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A POLICY ANALYSIS OF FOREST HEALTH
PROBLEMS AND THEIR EFFECTS OF FISH
AND WILDLIFE HABITAT

FINAL REPORT

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A Policy Analysis of Forest Health Problems and Their Effects on Fish and Wildlife Habitat

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EXECUTIVE SUMMARY

The health of our forests has recently become a concern of forest managers, politicians and the public, particularly in the inland west. Many people define “forest health” primarily in terms of dead and dying trees as a result of insects, disease, and fires. Others are concerned with the effects of various forest conditions on the fish and wildlife resources associated with forest ecosystems. The purpose of this project was to examine the literature on the concept of forest health and the current forest conditions, especially in southwestern Idaho and the Boise National Forest, to better understand the potential effects of these conditions and the implications of forest health strategies and policies on the fish and wildlife and their habitats.

The report begins with an overview of the evolution of forest health issues from sustained-yield management of a small number of commercial tree species to concepts related to forest ecosystem health, sustainability, integrity, ecosystem management and adaptive management. New vocabularies and new approaches to forest management are briefly discussed. The literature is extensive and voluminous, especially in the past five years, yet it is inconclusive on the meanings of terms and the management practices necessary to achieve healthy forest ecosystems.

Today’s forest conditions in the inland west reflect both man-made and natural disturbances as a result of management practices and climatic conditions. The literature on the impacts of these disturbances on fish and wildlife resources is reviewed. Species-specific management, such as the use of management indicator species, has been the traditional approach to maintaining biological diversity on federal lands in the face of continual disturbance. Recent concerns have focused on maintaining and restoring ecosystem elements and process across landscapes.

A major topic of discussion in the literature is the selection of indicators to monitor ecosystem health. Forty years of ecological research have identified many such variables and indicators, but agreement among experts on the “best” indicators to monitor is lacking, as are long-term monitoring data. This is especially true of fish and wildlife data. Relative abundance of a species has been the recommended high priority indicator by the Environmental Protection Agency. However, many wildlife biologists are critical of the use of indicators. There is concern that the selection of species is too general and threatened and endangered species are often used because of their protected status rather than because of their ability to indicate habitat abundance, habitat quality or other fish and wildlife species population trends.

Some argue that physical habitat features may be more useful and practical. However, the presence of habitat does not guarantee that animals will occupy it. It is important that the indicators that are used are relevant to clearly stated goals and objectives of the management activity. Peer review of the selection of indicators, methods of data collection, statistical analysis, interpretations and recommendations is also critical. Many authors argue for comprehensive monitoring plans, including the design of fish and wildlife resource monitoring programs, which accommodate a wide variety of temporal and spatial scales. Proposals for integrated monitoring at landscape scales are briefly discussed.

Recent activities to develop and implement a forest health strategy on the Boise National Forest are reviewed. The Deadwood Ecosystem Analysis Project (DEAP) was originally chosen to use as a case study for this project. One component of the DEAP was the development of a forest health monitoring program that included fish and wildlife indicators linked to the landscape-level ecosystem focus. The passage of the Salvage Rider in July 1995 by the U. S. Congress

resulted in the DEAP being broken into smaller site specific projects and the analysis is now the Deadwood Salvage Sale.

Many scientists and others are concerned about the potential impacts to fish and wildlife when salvage logging activities are used to “treat” forest health, especially when salvage operations are moving forward without long-term plans for restoration of forest health and are not adequately assessing fish and wildlife opportunities and constraints. They also contend that salvage sales are proceeding outside the framework of ecosystem management and little monitoring and evaluation to guide subsequent direction and gain knowledge are being done.

In conclusion, it must be recognized that “forest health” is a concept; it may not be a realistic forest management goal. At this time, we cannot determine health from an ecological standpoint and we have no consensus in society or the natural resource professions as to what is a “healthy” forest. Currently, forest health best represents a conceptual way to look at opportunities and constraints as we move forward in the evolution of our land management philosophies.

Forest ecosystems are a major part of the biological, social, political, and economic landscapes of the inland west. Priorities about societal and management goals for fish and wildlife habitats and populations across these landscapes and about what distribution of habitats and animals constitute a healthy ecosystem are ambiguous. Our scientific level of knowledge concerning such concepts as connectivity, persistence, viability and diversity over landscape scales is still in its infancy. Data are not conclusive and models have not been validated with long-term monitoring data. At present it is not possible to accurately predict the long-term consequences to fish and wildlife of the policies and actions being proposed to remedy the forest health situation in the inland west.

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INTRODUCTION

The health of the forest has recently become a concern of forest managers in the Intermountain Region, especially the Boise National Forest in southwestern Idaho, and in other parts of the United States. Many scientists and managers focus forest health discussions primarily on dead and dying trees as a result of insect and disease outbreaks and fire-caused impacts. Others assert that little attention has been given to the effects of various forest health conditions on the fish and wildlife species and the habitats they depend upon in forest ecosystems. This report is an attempt to examine what is known about the relationship between current forest health conditions and the effects on fish and wildlife components of the forest.

The concept of forest health entered the mainstream forestry literature in the 1980s in reference to a recognized decline in tree health. The term itself has evolved to include many definitions, theories, and concepts. With the onset of the USDA Forest Service's *New Perspectives* (Salwasser 1991) initiative and, subsequently, *Ecosystem Management* in the 1990s, the term forest health has been incorporated into the concepts of ecosystem health, sustainability, ecosystem management and others. There is a plethora of available literature attempting to define and apply these concepts to forest management philosophy and direction; however, few empirical studies exist at this time.

The purpose of this report, as defined in Agreement INT-93841-RJVA between the University of Idaho and the USDA Forest Service Intermountain Research Station, is to focus on fish and wildlife resources within the context of the broader "forest health" debate. The original objectives in the contract were to:

- 1) Review the consequences of forest conditions caused by abnormal levels of insect, disease, and fire-caused impacts as related to their effects on fish and wildlife habitats;
- 2) Review fish and wildlife responses to disturbance regimes;
- 3) Analyze landscape-level monitoring regimes for fish and wildlife and assess their use as measures of forest ecosystem health; and
- 4) Analyze potential impacts of alternative remedial policies being proposed for improving forest health and the effects of those policies on fish and wildlife habitats.

Over the course of this project, these objectives were modified as follows:

- 1) Review the evolution of today's land management philosophies with emphasis on the expansion of forest health concepts to include fish and wildlife habitats and populations;
- 2) Review fish and wildlife responses to disturbance regimes;
- 3) Examine species management approaches which can be used to predict species responses to disturbances which occur as a result of natural events or management practices;
- 4) Analyze landscape-level monitoring regimes for fish and wildlife and assess their use as measures of forest ecosystem health; and
- 5) Review current remedial policies being proposed for improving forest health on the Boise National Forest and discuss the probable effects of those policies on fish and wildlife species and habitats.

The report begins with an overview of the evolution of forest health issues in reference to ecosystem health, sustainability, integrity, ecosystem management and adaptive management. This is followed by a discussion of the current situation, with particular reference to the Boise National Forest (BNF), including differing perspectives on forest health. Subsequent sections of the report will address the modified objectives as presented above.

Evolution of Land Management Philosophies

Arguments concerning the evolutionary path of land management philosophies have increased in scientific and political discussions since the early 1980s (McIntosh 1985). This is due to the increasing demands, conflicts, and challenges in natural resource management as well as new developments in ecological theory and practice. The result has been a major change in the way natural resource professionals are talking about the land and resources they manage (see, for example, Aplet et al. 1993, Noss and Cooperrider 1994, Woodley et al. 1993).

The evolution from sustained-yield management (usually expressed in terms of timber outputs) of a relatively small number of commercial tree species to the protection and sustainability (often expressed in terms of ecological conditions) of forest ecosystems is changing some of the fundamental premises in forest management. A new vocabulary is emerging with related concepts such as forest and ecosystem health, ecosystem sustainability, ecosystem management, ecosystem resilience or persistence, biological integrity, biodiversity and landscape ecology (Aplet et al. 1992, 1993, Grumbine 1992, Costanza et al. 1992).

New forest management strategies are also emerging such as frameworks to implement ecosystem management (Bormann et al. 1994, Haynes et al. 1995), landscape level analysis [also referred to as watershed analysis or ecosystem analysis] (REO 1995), adaptive management

(Everett et al. 1994c), and integrated monitoring (see, e.g., Everett et al. 1994a). Included in monitoring efforts is the need to address landscape-level long-term monitoring protocols for fish and wildlife and assess their potential as indicators of forest ecosystem health. [Note: the term *landscape* is used in this report to refer to relatively large areas that have similar and repeatable patterns of physical features, habitats, and human communities (Aplet et al. 1993).]

Forest Health. Although forest health is a relatively new term in forestry, notions of *land health* have existed for many millennia (Norton 1991). Most contemporary views of forest health stem from the writings of Aldo Leopold (Leopold 1949, Callicott and Flader 1992). Leopold wrote of the "land sickness" concerning symptoms of reduced vegetation cover and soil erosion. He argued for the practice of land health in which practitioners would seek to maintain the sustainability of ecological conditions and processes by conserving the ecological integrity or diversity of the land.

The term *land health* appeared again in reference to the forest tree decline phenomenon that became a subject of scientific inquiry in the 1980s (Smith 1985, 1990, Waring 1980). Today, "forest health" is the term more commonly used. It has many definitions; there is no consensus in the literature on a common definition or conceptual understanding. Definitions range from objective-oriented ones to ones that are ecosystem-oriented (Kolb et al. 1994).

For example, a healthy forest has been defined as a "condition where biotic and abiotic influences on the forest do not threaten management objectives for a given forest unit, now or in the future" (McIntire 1988:7). It has also been defined as a "fully functional community of plants, animals, and their environment. In ecological terms, a healthy forest might be a balanced ecosystem" (Byler and Zimmer-Grove 1991:104). The USDA Forest Service defined forest

health as "the condition of the forest based on the diversity of natural features of the landscape, distribution of plant communities exhibiting varying stages of succession, and the degree to which naturally occurring fauna occupy habitats that are varied and equitably distributed across the landscape" (Gast et al. 1991:7). Recently, the term *ecosystem health* has entered the discussion.

Ecosystem Health. Health of a forest ecosystem or landscape is more complex than the health of a stand of trees. Jack Ward Thomas relates *ecosystem* health and *forest* health:

"Ecosystem health incorporates resiliency and diversity of composition, structure, and function--including the variety of genes, species, plant and animal communities, and the processes that connect them through time. Active forest management to maintain forest health is rooted in the concept of healthy ecosystems and reflects a condition where biotic and abiotic influences do not threaten resource management objectives." (1995:1)

Forest health, in this broader ecosystem context, depends on both society's objectives for the forest and on the interaction of biotic and abiotic processes that produce the range of habitats required for the continued existence of native species (Kolb et al. 1994, O'Laughlin et al. 1994). O'Laughlin and colleagues produced an extensive review of forest health and defined it as "... a condition of forest *ecosystems* that sustains their complexity while providing for human needs." [emphasis added] (1993:3).

Kolb et al. (1994) assert that a more useful definition of forest health from an ecosystem perspective would include specific types and rates of ecological processes, and numbers and arrangement of structural elements that characterize diverse, productive, forest ecosystems in major biogeographic regions. Their definition considers a healthy forest to have the following characteristics: 1) the physical environment, biotic resources, and trophic networks to support productive forests during at least some seral stages; 2) resistance to catastrophic change and/or the ability to recover from catastrophic change at the landscape level; 3) a functional equilibrium

between supply and demand of essential resources (water, light, nutrients) for major portions of the vegetation; and 4) a diversity of seral stages and stand structures that provide habitat for many native species and all essential ecosystem processes. This definition spans the gap between natural landscapes (i.e., non-commodity outputs, roadless) and artificial landscapes (i.e., intensively managed primarily for timber products). This definition does refer to providing *habitat* for native species (and one assumes this includes native fish and wildlife species). However, it does not include any recognition of the presence or absence of healthy fish and wildlife *species* as a characteristic of a healthy and/or productive forest.

Sustainability. Today, forest health is also embodied in the concept of sustainable ecosystems (see, e.g., Aplet et al. 1993, Noss and Cooperrider 1994). Specific issues related to sustainability include the health of forests and forest ecosystems, their wildlife diversity, their resilience to stress and climatic change, their productivity of wood and other resources, the environmental services provided by forests, and their aesthetic values (Aplet et al. 1993).

The November 1993 issue of *Ecological Applications* presents a forum on the science of sustainability and sustainable development. The premise of the forum is that biological science is not and should not be the central focus of the issue of sustainability but that sustainability requires recognition of the linkages among physical, biological, and socioeconomic systems. Others are looking at the issue of sustainability in the context of sustainable forestry (see, for example, Fri 1991, Gale and Cordray 1991, Gregg 1992) and the sustainability of forest ecosystems across the landscape (Constanza et al. 1992, Noss and Cooperrider 1994). Consideration of sustainability has extended the concept from simply "dead or dying trees" to concerns over watershed health

(that is, hydrologic functioning), air and water quality, and fish and wildlife species population changes and loss of habitat (Grumbine 1992, Marcot et al. 1994, Wissmar et al. 1994).

Integrity. Another term that has become associated with health is ecological integrity or biological integrity. Leopold (1949:262) discusses integrity: "A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise." Cairns (1977) offered a more measurable definition that brings together social and ecological elements by stating that biological integrity is the maintenance of the community structure and function characteristic of a particular locale or deemed satisfactory to society. A more quantitative definition of biological integrity was developed by Karr and Dudley (1981:56) as: "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region." Therefore the existence of integrity suggest that "ecological health" is being protected (Woodley et al. 1993). Ecological health is the condition when a system's potential is realized, its condition is stable, its capacity for self-repair, when perturbed, is preserved, and minimal external support or management is needed (Karr et al. 1986).

Ecosystem Management. The concept of ecosystem management appeared in the literature as early as the 1930s (Shelford 1933). What is new today is the development and implementation of an ecosystem approach to natural resource management in light of concerns over biological diversity (Noss and Cooperrider 1994), ecosystem health (Constanza et al. 1992), sustainability (Aplet et al. 1993) and biological integrity (Angermeier and Karr 1994). Grumbine (1994) provides an extensive review of the literature concerning the dominant themes of

ecosystem management and offers this working definition: "Ecosystem management integrates scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term." (1994:31). Today's concerns about implementing an ecosystem-based approach to management have focused on the link between science and policy (Gale and Cordray 1991; Grumbine 1995, in press) and the law and ecosystem management (Brosnan 1995, Keiter 1990, Schlager and Freimund 1994).

The connection between ecosystem management and the management of fish and wildlife species has been explored in recent literature, especially concerning the link to endangered species management (Quigley and McDonald 1993) and biological conservation (Aplet et al. 1992, Probst and Crow 1991, Trauger and Hall 1995). In March 1994, the USDI Fish and Wildlife Service (USFWS) called for an ecosystem approach to fish and wildlife conservation. The vision of the Service's new role in an ecosystem approach was "conservation of the Nation's natural animal and plant diversity through perpetuation of dynamic, healthy ecosystems." (USFWS 1994:3). Their definition of an ecosystem approach to fish and wildlife conservation means protecting or restoring the function, structure, and species composition of an ecosystem while providing for its sustainable socioeconomic use (USFWS 1994). In 1992, the national forests were directed to change their land management mission from multiple-use sustained yield management focusing on outputs to "ecosystem management" (Robertson 1992). Under this policy, ecosystem sustainability is key (Overbay 1992).

Adaptive Management. An adaptive management approach to ecosystem management has been advocated (FEMAT 1993). Adaptive management is a continuing process of planning,

monitoring, researching, evaluating, and adjusting management approaches (Hollings 1978, Walters 1986). It involves bounding management problems in terms of explicit and hidden objectives; representing existing understanding of systems; representing the uncertainty in relation to management actions; and designing balanced policies that provide for continuing resource production while simultaneously probing for better understanding and untested opportunity (Walters 1986).

Volkman and Lee (1994) discuss adaptive management approaches to ecosystem policy as a series of experiments from which we can learn, acknowledging that the nature of these experiments must be decided in the political forum. They also recommend adaptive management must be pursued even while policy- and law-makers determine whether and how recommendations specific to ecosystem-based approaches or projects are to be implemented. At this time, most strategies to implement ecosystem management, restore forest health or address sustainability of forest ecosystems are conceptual. Therefore, an adaptive management approach with integrated monitoring as a primary feedback loop should be a priority.

Table 1 provides the reader with an extensive list of recent works which discuss this evolution of land management philosophies. The focus in the literature has been primarily on the health of the trees as the central issue in the forest health debates. However, it is recognized that the concept of forest health must be expanded to ecosystem health. Critical components of forest ecosystems include fish and wildlife resources. It is the purpose of this report to examine the concept of forest health and the current forest conditions, especially in southwestern Idaho and the Boise National Forest, to better understand the potential effects of these conditions and the implications of forest health strategies and policies on the fish and wildlife and their habitat.

Table 1. Literature concerning the evolution of land management philosophies.

Source	Ecosystem Management Adaptive Management	Forest Health Ecosystem Health	Integrity	Sustainability
Alverson et al. 1994	X		X	
Angermeier and Karr 1994			X	
Aplet et al. 1993, 1992	X	X	X	X
Bormann et al. 1994	X			
Brown et al. 1987				X
Caraher et al. 1992		X		
Constanza et al. 1992	X	X	X	X
Cortner and Moote 1995	X			
DellaSala et al. 1995		X		
Ecological Appl. Nov 1993				X
Everett et al. 1994a, 1994c	X	X		X
FEMAT 1993	X			
Fri 1991				X
Gale and Cordray 1991				X
Gast et al. 1991	X	X		
Gatto 1995				X
Gerlach and Bengston 1994	X			
Gregg 1992				X
Grumbine 1992, 1994, 1995	X		X	
Haynes et al 1995	X			
Henjum et al. 1994	X	X		
Jensen and Bourgeron 1994	X	X		
Karr (and others) 1981-1993			X	
Kolb et al. 1994	X	X		X
Lee 1993	X		X	
Moote et al. 1994	X			
Morelan et al. 1994		X		
Noss 1990b			X	
Noss and Cooperrider 1994	X	X		X
O'Laughlin et al. 1993, 1994	X	X	X	X
Oliver et al. 1994		X		
Probst and Crow 1991				X
Quigley and McDonald 1993	X			
SAF 1993	X	X		
Salwasser 1994	X			
Samson 1992				X
Sampson 1993a, 1993b		X		X
Sampson and Adams 1994a, 1994b	X	X		
Schaeffer et al. 1988		X		
Slocombe 1993	X			
Steedman 1994		X		
Volkman and Lee 1994	X			
Walters 1986	X			
Wilklum and Davies 1995	X			
Woodley et al. 1993	X	X	X	

The Current Situation

Today's concerns about forest health center around past management practices (grazing, harvesting and fire exclusion) and weather patterns that have created conditions conducive to elevated levels of insect, disease, and fire-caused tree mortality) in the region's forests. Mortality has been greatest in dense and old stands, and in stands where past management practices and successful fire exclusion have encouraged the growth of tree species susceptible to pests, drought, and fire (i.e., in southwestern Idaho, a shift from ponderosa and other long-needed pines toward firs). Sampson et al. (1994a) state that under these altered conditions, competition for moisture and nutrients creates stress that may result in reduced growth, while opening the way for catastrophic outbreaks of insects, disease, and wildfire. And conditions exist that have led to the threat of large wildfires, soil erosion, impaired watershed functions, loss of wildlife and fisheries habitat, and human lives and property.

Since 1991, a number of studies have been conducted in the Pacific Northwest that have focused on the need to restore and maintain the health of the forest resources in the region (see, for example, Everett et al. 1994a, FEMAT 1993, Gast et al. 1991, Henjum et al. 1994, USDA FS/BLM 1994). In 1993, the Boise National Forest (BNF) participated in three activities that addressed forest health problems on the Forest, proposed and evaluated a forest health strategy and assessed the level of scientific knowledge concerning forest ecosystem health (Sampson and Adams 1994a, 1994b).

First, in June 1993, a symposium "Forest Health in the Inland West" was convened to address the nature of the forest health problems on the BNF. Participants concluded that overly-dense tree stands, species composition shift (from pine to fir), fire exclusion, and past harvest

practices were the primary underlying causes of deteriorating forest health (Morelan et al. 1994). The conclusion, although not unanimous among participants, was that doing nothing was more risky than doing something. Participants recommended that forest health be linked to ecosystem health and *challenged* the Forest Service to look beyond forest health to the forest ecosystem -- the soil, the wildlife, the watershed, and the fisheries (Gehrke 1993, Sampson 1993b).

Next, in November 1993, a workshop was held to assess the current state of scientific knowledge concerning the health of Inland West forests (Sampson and Adams 1994a, 1994b). Third, the Policy Analysis Group at the University of Idaho produced a report "Forest Health Conditions in Idaho" (O'Laughlin et al. 1993) that reviewed the current conditions of Idaho's forests, addressed the definition of forest health, and reviewed the ecological, social, and policy factors surrounding forest ecosystem health. As a result of these activities, the BNF identified restoring and improving the health of the forest ecosystem as one of its top resource management challenges (Sampson 1993b).

To understand the consequences of forest conditions caused by abnormal levels of insect, disease, and fire-caused impacts as related to their effects on fish and wildlife habitats we must recognize the dichotomy of forest health perspectives that exists among natural resource professionals and the public. It is not surprising that to a forestry professional forest health may represent trees at risk of mortality and to a fisheries or wildlife professional forest health may represent the loss of habitat and the declining diversity and abundance of vertebrate resources. A series of public meetings on the subject of forest health was held in the Blue Mountains of northeastern Oregon and southeastern Washington during the spring of 1991 to discuss the issue

of forest health. Examples of fish and wildlife biologists' perspectives as expressed during these meetings are:

"Healthy forests sustain viable populations of fish and wildlife. . . . Particular wildlife species or group of wildlife species require different things from a healthy forest. . . . Accommodation of this cross section of life forms is best handled through a dynamic continuum of habitats at the forest stand, plant community and landscape levels. . . . Managing for healthy forests also means reducing species vulnerability." (Starr and Quigley 1992:59)

"Another indication of the health of our forests is the growing number of endangered, threatened, and sensitive species. The reasons many of these species are in trouble is because of loss of habitat. This loss of habitat is an indicator of the loss of biological diversity. To have a healthy forest you MUST maintain biological diversity. . . . To maintain biological diversity we need to maintain all the existing habitats in sizes and spacing that meet the needs of all associated species. . ." (Starr and Quigley 1992:60)

"From a fish and wildlife standpoint, some level of "unhealthy" forest is desirable in many cases -- necessary if many of the fish and wildlife species now present in the forest are to remain as viable biological components of the many coniferous forest ecosystems examples of these: snags(i.e. standing dead trees) which are necessary to maintain viable populations of primary excavating . . . species. . . some level of old-growth forest . . . and an on-going source of dead wood in fish-bearing streams." (Starr and Quigley 1992:66)

Most resource professionals would agree the serious decline of forest health in the Inland West can be attributed to both natural conditions and to management actions that did not fully recognize the role of disturbances in sustaining forest health (Oliver et al. 1994). One factor is the large scale conversion of the landscape by management or natural events from one dominated by old-growth pines to forests with large proportions of true firs and Douglas fir which are more susceptible to insect outbreaks. This change has converted the regional landscape from one that absorbs disturbance to one that magnifies disturbances (Henjum et al. 1994), such as the potential for large stand-replacing fires. Land use practices (e.g., overgrazing, high grade logging, and fire

exclusion) have resulted in serious degradation of many of the region's ecosystems and have created abnormal ecosystem structures, landscape patterns, and disturbance regimes that are not consistent with the evolutionary history of the indigenous biota (Covington et al. 1994).

The critical issue in the forest health debate is not whether or not something should be done to address these landscape conditions. Most scientists and managers agree that some change in management is necessary to maintain or restore healthy forests. Socio-political realities dictate the need to reduce fire hazards and to provide revenue to rural communities dependent on resource extraction (DellaSala et al. 1995). Thus, the critical issues are how to expand forest health to include ecosystem health and how agencies can adequately address other ecosystem components such as water quality, endangered species and unique habitats.

Forest Health -- one perspective. In areas where insects, disease, and wildfire are causing total or near-total *tree mortality*, the evidence of forest health problems (as defined by many forestry professionals) is visual and stark (Sampson et al. 1994). In other areas, the evidence and mortality may be lacking, but major ecosystem setbacks are likely because of conditions that will inevitably lead to large, stand-replacing fires (Covington et al. 1994). Managers are challenged to take rapid preventive action to restore forests to conditions more similar to their pre-European settlement historical range of variability (Sampson et al. 1994). Strategies and policies to address forest health have included commercial thinning (to control species composition and stand density), prescribed burning (to reduce down and dead wood and other fuel levels in the understory) and salvage logging (to remove fuels and gain economic and other ecological goals).

Forest Health -- another perspective. DellaSala et al. (1995) concluded that the discussion of forest health needs to be expanded beyond tree health to include forest ecosystems

and their capacity to: 1) maintain viable populations of native species across their geographic range; 2) sustain critical ecosystem processes such as nutrient cycling, insects and disease, natural fires, and species interactions they support and maintain diverse communities of species and ecosystems; and 3) retain characteristic biodiversity and dynamic properties in the face of short- and long-term disturbance. Vertebrate wildlife will probably continue to be a primary surrogate for assessing biological diversity in forested ecosystems (Irwin 1994). Maintaining habitat for the vast array of elements of biodiversity will require maintaining habitat diversity (Aplet 1994).

Forest health - public perspectives. Public perceptions of the forest health debate vary widely. They stem from economic concerns of those communities who have relied on timber resource extraction to provide monies for community stability to those concerned with fish and wildlife not being adequately addressed in current plans for sales that emphasize forest health restoration. Some publics contend that environmental laws and regulations preclude the ability to capture the economic value of insect/diseased or fire-damaged trees and have all but halted the supply of timber to forest products industries and, consequently, to the communities. Other publics believe that fish and wildlife values (especially issues related to old growth habitat, road building and sedimentation, and disturbance or displacement of sensitive species) have not been incorporated into the forest health decision process.

Summary

Land management philosophies are continually evolving as we gain a better understanding of both the biophysical processes which take place in forest ecosystems and the societal importance of the resources associated with forest ecosystems. The concept of *forest health* is expanding to include many components of forest ecosystems. Concerns about sustainability and

integrity of ecosystems are leading to new management approaches, referred to as ecosystem management or adaptive management.

Many natural resource professionals in the Inland West, including those on the Boise National Forest, are currently attempting to address many of the concerns being raised about the condition of the forest. Today's forest condition is a result of disturbances related to past management practices and climatic conditions. The next section of this report will focus on reviewing our current abilities and proposed directions for predicting responses of fish and wildlife resources to such disturbances.

FISH AND WILDLIFE RESPONSES TO DISTURBANCE REGIMES

The second objective of this project was to review fish and wildlife responses to disturbance regimes. "Disturbance" can be either events considered *natural* (such as fires, floods, insect and disease epidemics) or man-made events (such as prescribed fire, timber harvest, road construction). Disturbance, either natural or man-made, may enhance both floral and faunal diversity and help maintain vigor and vitality in the ecosystem. Disturbance presents a paradox to management: the continued existence of particular species (particularly valuable commodity species) or habitats often requires disturbance of some type, but disturbance may simultaneously lead to the degradation of natural communities by promoting invasions (Hobbs and Huenneke 1992). The response of any community to a disturbance is determined by the attributes of component species. Disturbance frequency is also important; the time interval between successive disturbances effects community response (Hobbs and Huenneke 1992).

Any disturbance or management regime will benefit some species and not others. The decision may be easy (although the techniques for management may not be) when the choice is between native and non-native species. The dilemma is more difficult when non-natives have some appeal of their own; it is even more difficult when the choice is between two natives (Hobbs and Huenneke 1992). Forest health should include assessing biodiversity in relation to short and long-term disturbances. Maintaining habitat for the vast array of vertebrate resources will require maintaining habitat diversity.

Historically, habitat diversity was maintained through the heterogeneous distribution, across space and time, of the primary elements affecting ecosystem structure: climate, soils, species availability, and disturbances such as fire, wind and flood. The historical model, which viewed ecosystems either existing in a persistent steady-state or returning to one, has been replaced by the contemporary model in which ecosystem structure and function is believed to be influenced by occasional disturbances (Aplet 1994). At present, there is a critical need to understand historical forest disturbances as agents of change, the disruption of these historical disturbance regimes (changes in fire regimes, tree insect and pathogens dynamics and hydrologic regimes) and the ecosystem responses to altered disturbance regimes. This includes changes in vertebrate habitat quality and availability, population changes and implications.

Morgan et al. (1994) state that the historical range of variability (HRV) concept characterizes fluctuations in ecosystem conditions or processes over time by describing variations in diverse characteristics, such as tree density, vertebrate population size, water temperature and frequency of disturbance rates. It also has the ability of being applied to multiple spatial scales. The concept of historical range of variability may provide a window for understanding ecosystem

conditions and processes prior to their alterations since Europeans arrived in the Inland West (Morgan et al. 1994, Swanson et al. 1994). Morgan et al. (1994) also state that there is evidence for the relationship between historical ecosystem behavior, especially the process of disturbance, and the maintenance of biological diversity. Everett et al. (1994a) described the threats to the diversity of eastside ecosystems as: intensified or altered disturbance regimes (fire, insect, disease, flood, grazing); acute reductions in quantity and quality of some land and aquatic plant and animal habitats; acute reductions in populations of some land and aquatic plant and animal species; and significant discontinuities in some land and aquatic plant and animal habitats. Deleterious effects on biological diversity and ecosystem function are often observed where ecosystem conditions and processes have been altered significantly from the historical range of variability.

The HRV concept is limited by our understanding of the spatial and temporal scales of structures and patterns across the landscape; the vertebrate responses to disturbance regimes; and the cause of observed phenomena interpreted from the historical record. In addition, for many conditions and processes, the historical record reveals little information (Morgan et al. 1994). For vertebrate resources and terrestrial ecosystems, sufficient information on historical distributions is lacking. More information is available for aquatic systems, especially anadromous salmonids. The Western Section of The Wildlife Society concluded that considerable work remains before defensible guidelines for conserving a desirable range of species, habitats and processes are identified and incorporated into management objectives and initiatives for forest health.

Gast et al. support the application of forest health initiatives and fish and wildlife resources:

"If we accept the assumption that past changes in wildlife populations, or at least some factors of the present-day wildlife spectrum, are the direct result of changes in forest composition, structure, and distribution, then we must assume that changes in forest composition that tend to "mimic" natural forces and restore forest health will have an effect on wildlife species which co-evolved with those forest types. Therefore, it is likely that vegetation management designed to promote forest health will be reflected to some extent by change in faunal species populations." (1991:VI-10):

Changes in wildlife habitat occur over time in any ecosystem. But changes associated with declining forest health in the western U. S. may be more dramatic than gradual successional changes in both geographic scope and the suddenness of the habitat alteration (Martin 1994).

Management Activities

It would appear that management activities that attempt to emulate natural disturbances at a periodicity that is part of the natural cycle would be desirable. Although there are some who feel that our management activities cannot emulate natural disturbances (see, e.g., DellaSala et al. 1995), the consensus among professionals appears to be that some form of management practices must be implemented to achieve forest health goals.

Wildlife. The traditional view of resource management has not always considered the effects of disturbance patterns on wildlife species distribution, dispersal and local population viability at the landscape level. Disturbances such as timber harvest and/or extensive stand replacing fires often result in the removal of late successional/old growth stands. Such stands support high densities of birds and arthropods; reduce snag densities for cavity nesters and downed dead wood that support predators that prey on insect populations and provide wood potential for stream channels; and alter other unique habitats, such as riparian zones which are critical for the maintenance of a productive fishery and increased water quality. Understanding

the role of both natural and management disturbances in forest ecosystems is a critical component in the evolution of the management philosophies of today's natural resource managers.

Irwin et al. (1989) presents a thorough review of wildlife use of managed forests. They review the scientific basis for wildlife-habitat relationships and present the need to develop a greater understanding of wildlife response to natural and human-induced disturbances as a valid process for understanding forestry-wildlife interactions. They also discuss the need to conduct hierarchical analyses in space and time to assess the collective needs of plant, fish and terrestrial wildlife populations and species and bring together the essential components of landscapes, watersheds, and regions collectively to meet long-term habitat requirements for threatened, featured or other species. Wildlife populations respond to functional redundancies caused by multiple interactions among landforms, soils, and vegetation. Scientists must clarify the primary determinants of wildlife habitat selection, which is a behavioral process linking populations with ecosystem processes (Irwin 1994).

Adaptive management experiments are under way to determine the effect of single-tree selection of old-growth to encourage regeneration, and at the same time, retain the characteristics of old-growth so that those wildlife species associated primarily with it will continue to use the stand (Oliver et al. 1994, Aplet 1994). Others disagree that silvicultural treatments can mimic natural disturbance or maintain stand elements or landscape features necessary for maintaining biodiversity (DellaSala et al. 1995).

TFW (1991) proposes a design to develop a database of knowledge and methods to evaluate wildlife responses to changes in forest habitat conditions as a result of timber harvest at watershed or landscape levels. When managed forests are reviewed from a landscape perspective,

managers should be concerned with the spatial and temporal patterns among stands. At the landscape level, for example, the distance between stands, connectivity of stands, and conditions surrounding stands should be considered. At the stand level, managers should be concerned with habitat features such as stand size, shape, and seral stage. The response of wildlife populations at the landscape and stand level will depend upon the particular life history of a species, the environment (habitat and other species present), and the species' population structure, which reflects the interaction of life history and environment (Gilpin and Soule 1986). Analysis will need to include landscape analysis (wildlife habitat from a landscape perspectives at several levels) and wildlife data analysis (community- and species-level responses) (Irwin et al. 1989).

Erickson and Toweill (1994), examining forest health and wildlife management on the Boise National Forest, presented an evaluation of the effects of forest management, fire exclusion, and future risks of extensive wildfire on wildlife species distribution, dispersal, and viability/persistence. Changes in stand structure, species composition and disturbance patterns, particularly, the trend towards extensive stand replacement fire, can affect plant and animal community diversity and local wildlife populations distribution, dispersal and viability.

A key element for wildlife interest is defining the geographic location of sensitive species, habitats and associated hazards from current declines in forest health and planned management initiatives for restoration (Martin 1994). Marcot et al. (1994) suggests that management of unique habitats includes mapping the location and extent of the habitat and superimposing proposed management activities to identify areas of potential conflict. Assessing wildlife responses to land use is complicated because environmental gradients constrain the effects of spatial patterning of stands (Turner 1990).

Changes in disturbance frequency and intensity can have substantial effects on habitat distribution and patch size (Turner et al. 1989). The pattern of successional stages across the landscape may enhance or retard the spread of disturbances; disturbances may generate new landscape patterns (Franklin and Forman 1987). National Forest Management Act (NFMA) direction for diversity and population viability, suggest that land managers analyze management activities in relation to past, current, and predicted patterns (Erickson and Toweill 1994).

A quantified understanding of the influences of landforms and soils on animal/plant interactions is also needed (Haufler and Irwin 1994, Irwin 1994). Ecologically-based land classification systems could provide information for more reliable predictions of wildlife population responses to these interdependent physical and biotic factors (Haufler and Irwin 1994).

Fisheries. Fisheries responses to disturbances have also been studied (Marcot et al. 1994, Wissmar et al. 1994, Reiman and McIntyre 1993). Marcot et al. (1994) presents an example of managing for sustainable native fish in eastern Oregon and Washington that concentrates on the types of disturbance and the adaptations and resiliency of stream fishes to disturbances. They propose that the distribution and abundance of coldwater fishes be used as indicators of biological integrity/health for watersheds.

Reiman and McIntyre (1993) consider the implications of habitat disturbance and land-use management on bull trout. They review the process leading to population extinction of any species and use existing information to consider extinction risks for bull trout. They recommend additional research be concentrated on the importance of scale, temporal environmental variation, distribution, connection of habitats and the associated risks of extinction.

Table 2 presents literature pertaining to disturbance and recovery of systems.

Table 2. Literature concerning disturbance regimes, recovery and landscape analysis, classification and scales.

Source	Disturbance/Recovery	Landscape Analysis/ Classification/ Scales
Albert 1993		X
Attiwill 1994a, 1994b	X	X
Baird et al. 1994	X	
Baker 1992	X	X
Bourgeron et al. 1994	X	X
Cairns 1990	X	
Cole 1987	X	
Detenbeck et al. 1992	X	
Erickson and Toweill 1994	X	X
Glenn and Collins 1994		X
Gore et al. 1990	X	
Haufler 1994a, 1994b		X
Haufler and Irwin 1994		X
Hobbs and Huenneke 1992	X	
Hunter 1990, 1991	X	X
Irwin 1994		X
Irwin and Wigley 1993	X	X
Kinsolving and Bain 1993	X	
Landres 1992		X
Lindenmayer 1995	X	
Morgan et al. 1994	X	X
Naiman 1992	X	
Poff and Ward 1990	X	
Potter and Kessell 1980	X	
Reice et al. 1990	X	
Reiman and McIntyre 1993	X	X
Saunders et al. 1991		X
Sedell et al. 1990	X	X
Sousa 1984	X	
Turner et al. 1989	X	
Yount and Niemi 1990	X	

Summary

Species-specific management is a traditional approach to managing for biological diversity on federal lands. It focuses on amount, distribution, and quality of habitats. In recent years, however, other aspects of biological diversity have been recognized as important to assess and maintain. These include unique and declining habitats, plant and animal communities, and ecosystems. Management programs must be grounded in a broader context than single species. They should be designed to maintain and restore elements and process within landscapes. A fundamental reality of landscape management is that not all system components can be tracked effectively. Therefore, because of their size, sensitivity to disturbance, relative ease of monitoring, and appeal to the public, vertebrates will be critical in management programs (Henjum et al. 1994).

The next section of this report discusses species management considerations for inventory and monitoring. Some of the concerns and challenges present in historical and recent applications of concepts, such as Management Indicator Species, ecological indicators and indicators of biodiversity will be discussed. Currently proposed strategies for assessing fish and wildlife responses to disturbances that incorporate these and other species management considerations will be presented.

SPECIES MANAGEMENT APPROACHES

The third objective of this project was to examine species management approaches which can be used to predict species responses to management practices (man-induced disturbance) and natural disturbances on the landscape. The literature on species management also provides guidance in selecting appropriate parameters to use in a monitoring program, which will be discussed in the next section.

Several approaches exist which provide choices in evaluating and assessing fish and wildlife responses to various forest management activities. These approaches can be categorized as follows: management indicator species, ecological indicators, indicator guilds, species-habitat matrices, coarse-filter and fine-filter species management, and using biodiversity to identify indicators.

Use of indicators. Indicators serve many purposes: as indices of environmental conditions that are too difficult or expensive to measure directly (Landres et al. 1988); as measurable surrogates for environmental values, such as biodiversity (Noss 1990a); as indications of the effects of management activities and resultant environmental stress (Hunsaker and Carpenter 1990); and as measures that index population responses of other species (Morrison and Marcot 1995). The use of indicator species to monitor or assess environmental conditions is a firmly established tradition in ecology, environmental toxicology, agriculture, and forestry and wildlife management. Landres et al. (1988), however, believe that despite increased use, the conceptual bases, assumptions, and guidelines for using ecological indicators have not been adequately examined.

Management Indicator Species

The National Forest Management Act (NFMA) (PL No. 94-588) and its regulations (36 CFR 1980) require forests to select and monitor a set of management indicator species (MIS). This species-specific management of fish and wildlife is a traditional approach focusing on key factors of habitat such as food, cover, and water in determining the amount, distribution, and quality of habitat needed for a species.

NFMA provided only general guidance (e.g., "provide for the diversity of the plant and animal communities based on the suitability and capability of the specific land area . . .") to accomplish its objectives (Sec 6g 3(B)). The NFMA regulations included three management directives for fish and wildlife: 1) viable populations of existing forest vertebrates must be maintained and "well distributed"; 2) certain species must be chosen and used as "indicators" of the effects of management on forest ecology; and 3) timber management and other management practices that result in serious adverse effect on fish habitat must be constrained [36 CFR 219.19].

The Committee of Scientists appointed to write the regulations to enact NFMA attempted to overcome the arduous task of providing for all native species by recommending the Management Indicator Species (MIS) concept. MIS are individual species or species groups that are selected to index population responses of another species in the ecosystem (Morrison and Marcot 1995). The theory was that the use of MIS would ensure that well-distributed, viable populations of existing vertebrates would be maintained. The MIS concept allowed forest planners to select a reasonable number of vertebrates and invertebrates to act as "proxies" for all others (Wilkinson and Anderson 1987). Management indicator species differ

from other types of indicators in that they are species (in contrast to habitat characteristics) and they indicate the effects of management activities (in contrast to effects of other events such as natural disturbances) on forest resources (not solely on other species) (OTA 1992). The use of MIS assumes that some relationship exists between a prescribed management activity and the presence or abundance of MIS (Patton 1987).

The regulations identify five categories to consider in selecting MIS species: 1) threatened and endangered species; 2) species sensitive to intended management; 3) game and commercial wildlife and fish; 4) nongame species of special interest; and 5) ecological indicator species. Threatened and endangered species are designated by state and federal agencies. Sensitive species and nongame species of special interest may be selected by regional offices or in some cases by local forest planners. Nationally significant game and commercial animals are chosen by wildlife planners in the USDA Forest Service national headquarters. The fifth category, ecological indicators, is defined as "plant or animal species selected because their population changes are believed to indicate the effects of management activities on other species of selected major biological communities or on water quality" (Wilkinson and Anderson 1987:300), have been selected by few forest planners.

The NFMA regulations require that each of the five MIS categories shall be represented "where appropriate." This qualifier, added during the 1982 revision of the regulations, is not specifically defined and gives the Forest Service some discretion. The selection of MIS is mandatory; the choice of species is subject to the "where appropriate" clause. Examples of MIS for wildlife on the Boise National Forest are: meadow vole and red-backed vole (sensitive

to intended management); elk (game); and pileated woodpecker (nongame). Threatened and endangered species are automatically included according to federal mandates.

Once MIS are chosen, objectives for the maintenance and improvement of habitat must be established for each species and each planning alternative. The objectives must be stated in terms of quantity and quality of habitat and population trends of the MIS. Monitoring MIS populations is deemed essential to verify and modify the forest plan assumptions about the effects of timber harvesting and other management activities on wildlife and fish. However, using traditional approaches focused on individual species and their habitats may not provide for some management objectives, such as unique, scarce or declining habitats, and some entire plant and animal communities and ecosystems (Noss and Cooperrider 1994). The challenge is to manage fish and wildlife species in a context of restoring forest ecosystem health that conserves biological diversity, site productivity, and sustainability of resources use (Everett et al. 1994a).

Although ecological indicator species (category five) are seldom used, they are considered the most reliable category of MIS by several authors (see, e.g., Hunsaker and Carpenter 1990, Noss 1990a). Ecological indicator species are those used to monitor the effects of management practices on other species. However, wildlife specialists on forest planning teams considered the relationship between species and general ecological conditions to be too complex and unreliable for planners to address in the first or second generation of forest plans (Wilkinson and Anderson 1987). Thus, local planners were usually confined in their MIS choices to locally important species in the first four categories. See Appendix A for the Boise National Forest Plan's description of MIS.

As with the indicator concept itself, several major concerns are inherent in the use of MIS. These include: no guidelines have been set for the selection of species; training and expertise to select, monitor, and analyze MIS have been lacking; and some species are ignored in the inventory process (Patton 1987). Many selection processes on forests have been criticized for choosing an insufficient number of indicators, others for choosing indicators that are not related to ecosystem conditions (OTA 1992).

The Forest Service now recognizes three overall categories of indicators: MIS, ecological indicators (discussed below), and management indicators (36 CFR 219, as amended Feb. 15, 1991). Management indicators is a broad concept that includes biological communities and special habitats rather than being limited to individual species. Although there is little evidence of use of this concept, it recognizes the important role of biological communities in providing diversity and the ecological contributions of various structural elements within those communities (Morrison and Marcot 1995). However, Morrison and Marcot (1995) emphasize that such a proposed change in the indicator concept would need thorough research as to how "communities" would be defined and described, what the community intended to indicate, and how a standard system to classify "biological communities and special habitats" would be developed.

Ecological Indicators

One approach to multiple-species management is through ecological indicators, which are elements of the biotic system that index changes in ecological conditions of an ecosystem. An ecological indicator can be a species whose presence, distribution, and population trend is assumed to index those of other species associated with a common geographic area or habitat

(Everett et al. 1994a) or an element of the biotic system that indexes changes in ecological condition (Hunsaker and Carpenter 1990). For example, ecological indicators of biological diversity would be concerned with changes in landscape patterns that are known to influence biodiversity. Changes in corridors between patches of natural habitat (O'Neill et al. 1994) might be such an indicator.

Congressional hearings in 1983 and 1984 on environmental monitoring led to the conclusion that despite hundreds of millions of dollars spent annually on environmental monitoring, federal agencies could assess neither the current status of ecological resources nor the overall progress toward legally mandated goals. In 1988, the Environmental Protection Agency (EPA) Science Advisory Board recommended that a program be implemented within EPA to monitor ecological status and trends, as well as to develop innovative methods for anticipating emerging problems. The program was called the *Environmental Monitoring and Assessment Program (EMAP)* (Hunsaker and Carpenter 1990).

The EMAP conceptual plan consists of the "Indicator Strategy" which attempts to define ecological indicators and their relation to ecological risk assessment (Hunsaker and Carpenter 1990). EMAP also proposes an "Indicator Selection Process" to identify potential, cost-effective indicators for implementation in a long-term monitoring program.

An indicator is defined by EMAP as a characteristic of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics, degree of exposure to the stressor, or degree of ecological response to the exposure. EMAP has identified seven ecological resource classes for monitoring. Among them are forests and inland surface waters. Indicators for forests are subdivided into seven categories: soil, water (physical habitat

features), vegetation, animals (relative abundance, demographics, and physical habitat features), ecosystem cycling, landscape patterns, and non-native plants and animals. Hunsaker and Carpenter's (1990) discussion of the categories of water, animals, and landscape pattern are summarized as examples.

Water. Water is ubiquitous and essential in all life forms while being spatially and temporally limiting in many ecosystems. The quality of water flowing through the landscape is a barometer of ecosystem health. *Macroinvertebrate counts* and *physical habitat features* are two indicators. Macroinvertebrates are sensitive to physical, chemical and biological stressors. Thus, presence/absence and abundance may provide a measure of health and complexity. Hydrological and physical habitat changes -- sediment, large woody debris, streambank stability -- could be measured to assess morphological condition of the stream and assess the suitability of these areas for fish habitats.

Animals. Vertebrate species occupy the higher trophic levels of forest ecosystems and may be useful as indicators of ecosystem condition. The concern in using animals as indicators lies in matching the organism to the landscape scale and time frame (season) of interest, since virtually all animals are mobile to a greater or lesser degree. Indicators include *relative abundance, demographics, and physical habitat features*.

Landscape pattern. Landscape pattern indicators include *habitat proportions (cover types)* and *landform*. Determining proportions of various vegetation cover types in a landscape is a basic measurement when considering both extent and change in vegetation and associated species compositions and diversity. Landform is generally described in a hierarchial

framework including physical characteristics and formative processes. Landform directly influences other indicators such as water, vegetation and animals.

EMAP is not an implementation plan. Its purpose is to propose a conceptual plan for describing ecological conditions; to define a common strategy for selecting and evaluating indicators of ecological condition, pollutant exposure, and habitat condition; and to present the design and evaluation of integrated statistical monitoring frameworks and protocols for collecting data on indicators.

Indicator Guilds

An approach related to that of ecological indicator species is that of species guilds (Hunter 1990). A guild is a group of species having similar ecological characteristics and exploiting the same class of environmental resources in a similar way (Morrison et al. 1992). Insectivorous birds may represent a guild. Guilds may be composed of ecologically similar species from a diverse array of taxa. Another example might be a seed-eating guild consisting of some rodents and birds. The assumption is that all species of the guild will respond similarly to changes in environmental conditions (Morrison et al. 1992), such as a change in habitat. This allows the manager to focus on just one representative species of the guild, and be confident that the other species would respond in the same manner. For example, Severinghaus (1981:187) proposed that "Once an impact on any one species in a guild is determined, the impact of every other species in the guild is known." This extrapolation is known as the "guild-indicator" approach (Block et al 1987). However, Landres (1992) points out that although it is assumed that species in a guild exploit the same class of resources, they may be very different in the other ways they use and respond to habitat. Points raised by

Verner (1984) and Landres (1992) referring to the unique responses of species to environmental conditions or disturbance and inferences derived from different geographical areas or seasons make extrapolation from one species to another difficult.

Species-Habitat Matrices

Another approach to multiple-species management is the use of species-habitat matrices. These matrices depict the relative quality of vegetation associations and seral stages and habitat needs for various life-history strategies, such as reproduction, feeding, resting and cover. One of the original species-habitat matrices was developed for eastern Washington and Oregon (Thomas 1979). This work led to the focus on wildlife habitat relationships within the USDA Forest Service.

Species-habitat matrices have been used in forest planning to help identify forest types, conditions, and seral stages, and special habitats -- such as riparian vegetation and snags -- for managing multiple species of wildlife (Patton 1992). Thomas (1979) developed life-form tables that group species according to components of habitats used for feeding and breeding. Similarly, Short (1982) developed a procedure that groups species into guilds based on habitats used for feeding and breeding. Based on an understanding of the changes in habitat that can be expected under various forest health conditions, the impact on the wildlife species traditionally associated with those habitats which are disappearing can be assessed. Predictions can also be made about the wildlife likely to live in the new habitats which are created as the health of the forest ecosystem changes.

Risk Assessment. Landres et al. (1988) recommended a potential strategy for monitoring wildlife is a species-habitat approach (Thomas 1979) that includes risk analysis.

Risk analysis formalizes the process of making decisions under uncertainty (Patton 1987) and entails assessing threats to continued existence of habitats (including edges, corridors, and mosaics) and species (population viability) (Erickson and Toweill 1994, BTCA 1994). Many managers have developed risk assessment methodologies in an attempt to utilize risk analysis in assessing species response to disturbances.

A review of risk assessment methodologies with respect to wildlife is provided by Jurgensen et al. (1994). Single-species risk assessments are usually more complex and include population and environmental variables in what is termed a population viability analysis. These analyses model the effects of demographic, genetic, or environmental variability on population stability to examine how expected time to extinction changes with environment, population structure, or behavior (Shaffer 1991).

Wildlife risk assessments for land management purposes typically stress the loss and fragmentation of habitats and how life history and population structure enable species to persist in spite of habitat fragmentation (Lemkuhl and Ruggiero 1991, Ruggiero et al. 1994). Identification of risk factors in multiresource ecosystem risk analyses presents problems different from species-oriented approaches because of analysis scale (Nash 1991). The ecosystem and its individual components must first be defined. Wildlife components may include multiple species with different habitat requirements and population structures, which have different responses to ecosystem stress and desired conditions. However, the same population viability analyses framework can be used to identify risk factors for individual species or functional groups of species (Jurgensen et al. 1994).

The Boise National Forest's Fire-Based Hazard/Risk Assessment model (BNF 1995) identifies forest ecosystems and their resources most at risk to severe, large wildfires burning outside the historical range of variability (HRV). The hazard/risk assessment model links five submodels: forested vegetation outside HRV, fire ignition, *wildlife habitat persistence*, watershed hazard, and *fish persistence*. Persistence is defined as the likelihood of a species or species habitat continuing in an area. These models estimate where wildfires would deplete late-successional habitat needed by old-growth dependent wildlife species and accelerate erosion or sedimentation which would increase the risk of extinction to some fish species.

The Fisheries submedial (BNF 1995) attempts to determine which subwatersheds and local fish populations are most at risk to the consequences of post-fire catastrophic events. These subwatersheds are to be prioritized for fire hazard treatments that conform to the recent conservation strategies for salmon and inland native fish (BTCA 1994, PACFISH 1994), following the scheme developed by Frissell (1993). The components of the Fisheries Risk Model include: 1) rating the presence of at risk species (chinook salmon and bull trout) as "high" and all others as "low"; 2) rating the relative population strength, which includes average relative population density (local strength, robustness and overall productivity of the habitat), and relative abundance based on the estimated total numbers of fish in the local population; and 3) isolation (connectivity to refuges or focal habitats in nearby subwatersheds and presence/absence of the migratory life history form). The model also recommends refining risks of extinction where additional information is locally available, such as temporal variability in recruitment or survival, population size, growth and survival, isolation, replication and synchrony, and scale (BNF 1995).

The wildlife submodel (BNF1995) identifies those wildlife habitats across the forest at greatest risk of low persistence. The model is based on the same premise as the fisheries submodel: it is intended to help managers prioritize where to do more intensive evaluation. The model does not specifically identify suitable habitat or population viability problems. The persistence model results in a likelihood rating from 1 (low) to 5 (highest hazard) of mid- and late-seral wildlife habitat. There are three components of the model: the delineation of mid- and late-seral stage wildlife habitat; the identification of wildlife habitat outside HRV; and the assessment of wildlife habitat not outside HRV remaining within the landscape. The model assumes that populations are strong where habitats are well presented (BNF 1995).

Coarse-Filter and Fine-Filter Species Management

Another approach that has been proposed for multiple species management is coarse-filter/fine-filter species management (Hunter 1990, 1991, Marcot et al. 1994). "Coarse-filter species management" assumes that conserving land areas and representative habitats, such as streamside riparian zones, will provide for the needs of all associated species, communities, environments, and ecological processes. A "fine-filter" approach specifically provides habitats or conditions for a single or few species. This view assesses individual stands or habitat components, such as, dead and down wood or snags. The goal is maintaining individual species because of their special values.

The macro view of habitat (coarse-filter) focuses on the landscape. The basic assumption is that the most efficient way to maintain biological diversity in a forested landscape is to have a diverse array of stands and thus a diverse array of ecosystems and their constituent species. This involves looking at tree species composition, age, and horizontal

structure across the landscape, that is, spatial heterogeneity. It also involves looking at the spatial distribution of stands across the landscape, specifically, edges and riparian zones and forest fragmentation. The goal is maintaining biological diversity. The problem with the coarse-filter approach is that some species are almost certain to slip through the "filter pores", because no ecosystem classification scheme is comprehensive enough to capture every species.

The goal of coarse filter strategies is to provide for ecosystem integrity or biodiversity by maintaining the necessary mix of ecosystems at an appropriate landscape scale (Kaufmann et al. 1994). Oliver (1995) conceptualized a strategy similar to Thomas (1979) but added a landscape ecosystem management approach which identifies the ecological layer represented by plant communities (as suggested by Haufler 1994a).

Another type of coarse filter strategy that addresses maintaining biodiversity and ecosystem integrity is based on historical ranges of variability (HRV) (Morgan et al. 1994, Swanson et al. 1994, Brooks and Grant 1992a, 1992b). This approach focuses on maintaining the mix of ecosystems across a landscape within the HRV. The assumption is that endemic species of a region evolved with and occurred within the historical range of ecosystem conditions and associated disturbance regimes. By maintaining ecosystems within this range, the needs of all species will be met (Morgan et al. 1994, Haufler 1994b).

While maintaining viable populations of species is an essential requirement of all strategies for ecosystem management, a fine filter strategy focuses on species or species groups and determines if these are provided across the landscape. A fine filter strategy attempts to maintain biological diversity by providing for the specific needs of individual species, guilds, or other groupings of species (Haufler 1994b). This approach assumes that a sufficient

knowledge base exists to adequately describe the habitat requirements for all species potentially occurring across the landscape and that the amount of habitat required to support a desired population of any species can be determined (Haufler 1994b). This approach also requires the use of indicator species or species guilds, which were discussed above.

Ecosystem Diversity Matrix. An alternative strategy to utilizing either a coarse filter or fine filter strategy independently is proposed by Haufler (1994b). This strategy involves creating an ecosystem diversity matrix that uses either habitat types or ecological land types as one axis, and a temporal scale such as successional trajectories or vegetative growth stages as the second axis. This matrix allows for the delineation and quantification of ecological units across the landscape that have similar characteristics in terms of historical disturbance regimes, existing vegetation structure and composition, future successional trajectories, and responses to disturbances or manipulations. The goal is maintain adequate ecological representation across the landscape. This can be evaluated through a species assessment by quantifying and evaluating the habitat requirements of any selected species.

Pluralistic Approach. Henjum et al. (1994) reviewed strategies for conservation, including fine filter and coarse filter approaches and a pluralistic approach. The pluralistic approach recognizes the multiple dimensions of biological systems and their importance to human society and to system persistence. It includes four hierarchical levels: regional landscape, community-ecosystem, population-species, genetics. It assumes that the most successful approaches to protect ecological health are grounded in programs that span the hierarchy, and include both elements and processes of biological systems.

Using Biodiversity to Identify Indicators to Monitor

Biodiversity as a consideration in environmental policy has been regarded as too broad and vague a concept to be applied to regulatory or management problems. However, Noss (1990a) proposed to identify measurable attributes or indicators of biodiversity for use in environmental monitoring and assessment. He also recommended the definition include processes, such as interspecific interactions, natural disturbances, and nutrient cycles and suggested that a more useful definition of biodiversity would be a characterization of biodiversity that identifies the major components at several levels of organization. Norse et al. (1986) described diversity at three levels: ecosystem diversity, species diversity and genetic diversity. The application of these levels could provide a conceptual framework for identifying specific, measurable indicators to monitor change and assess the overall status of biodiversity.

Williams and Marcot (1991) evaluated a process of addressing biodiversity as one of the core issues of development of a new Land and Resource Management Plan for the Klamath National Forest and the use of biodiversity indicators for analyzing and managing forest landscapes. Utilizing the recommendations and hierarchical structure of indicators proposed by Noss (1990a; see Table 3), Williams and Marcot (1991) proposed indicators of biodiversity classified as compositional parameters (naming elements within natural communities), structural parameters (representing ecological patterns within landscapes), and functional parameters (defining natural processes). See Table 4 for more information on these indicators.

Table 5 presents a literature categorization of species management considerations as discussed above.

Table 3. Indicator variables for monitoring and assessing terrestrial biodiversity at four levels of organization, including compositional, structural, and functional components, includes a sampling inventory and monitoring tools and techniques.

		Indicators		
Level	Composition	Structure	Function	Monitoring Tools
Regional Landscape	Identity, distribution, richness, and proportions of patch (habitat) types multi-patch landscape types; collective patterns of species distributions (richness, endemism)	Heterogeneity; connectivity; spatial linkage; patchiness; porosity; contrast; grain size; fragmentation; configuration; juxtaposition; patch size frequency distribution; perimeter-area ratio; pattern of habitat layer distribution	Disturbance processes (areal extent, frequency or return interval, rotation period, predictability, intensity, severity) nutrient cycling rates, energy flow rates, patch persistence and turnover rates; rates of erosion and geomorphic and hydrologic processes; human land-use trends	Aerial photos (satellite and conventional) and other remote sensing data; GIS technology; time series analysis; spatial statistics; indices (of pattern, connectivity, diversity, edge, layering, morphology)
Community-Ecosystem	Identity, relative abundance, frequency, richness, evenness, and diversity of species and guilds; proportions of endemic, exotic, threatened, and endangered species, dominance diversity curves, life form proportions, similarity coefficients, C4:C3 plant species ratios	Substrate and soil variables; hydrologic variables; slope and aspect; stream gradient; vegetation biomass and physiognomy; foliage density and layering; horizontal patchiness; canopy openness and gap proportions; pool/riffle/run ratios; abundance; density, and distribution of key physical intensities features (e.g., cliffs, outcrops, sinks) and structural elements (snags, down logs, woody material in water); water and resource availability; snow cover; water quality	Biomass and resource productivity, herbivory, parasitism, and predation rates, colonization and local extinction rates; patch dynamics (fine-scale disturbance processes); nutrient cycling rates; human intrusion rates and	Aerial photos and other remote sensing data; ground-level photo stations; time series analysis; physical habitat measures and resource inventories; habitat suitability indices (HSI, multi-species); instream flow assessments; hydrologic measurements (streamflow, channel stability, sedmt. transport); observations, mathematical indices (of diversity, heterogeneity, layering, biotic integrity-IBI).

Population-Species	Absolute or relative abundance; frequency; importance or cover value; biomass, density	Dispersion (microdistribution); range (macrodistribution); population structure (sex and age ratio); habitat variables (see community ecosystem); within-individual morphological variability	Demographic processes (fertility, recruitment rate, survivorship, mortality); metapopulation dynamics; population genetics (see above); population fluctuation; physiology; life history; phenology; growth rate (of individuals); adaptation.	Censuses (observations, counts, captures, signs, radiotracking); remote sensing, habitat suitability index; species-habitat modeling; population viability analysis
Genetic	Allelic diversity, presence of rare alleles, deleterious recessive	Census and effective population size, heterozygosity; generation overlap; heritability	Inbreeding depression rate of genetic drift; gene flow; mutation rate	Electrophoresis; DNA sequencing; offspring parent regression

Source : Noss 1990a

Table 4. Indicators of biological diversity for forest planning analysis

Parameter	Analysis Indicators	Rationale/Tools
Composition		
Vegetation and habitat types	Presence or absence of natural vegetation types. Amount of vegetation in each defined seral stage (other = nonforested, noncommercial, barrens)	Describe the current and future availability of plant and animal habitat in all stages. Describe the amount of vegetation communities in specific age classes - relevant to wildlife species with restricted range, dependent on specific components (snags) or old-growth.
Species Diversity	Management indicators; key habitat types - Acres of key habitats available - predictions of the impacts on species diversity Potential for invasion or spread of non-native species - ac/ha soil disturbed - revegetation standards - road density	Species and habitats that are rare or declining or function as ecological keystones, may influence the presence of others. The status of plant and animal species sensitive to management practices. Assessment should address standards guidelines and proposed management strategies and how will affect viability of these species.
Sensitive and endemic species	Status of special emphasis species as assessed by: - management emphasis of special plant/ animal habitats - standards and guidelines for species protection - habitat management and species recovery plans	
Community Diversity	Management, protection, and enhancement of special plant communities such as: - wetlands - meadows and glades	
Genetic Diversity of Tree Species	Timber harvest and plantation prescriptions	Species must be able to adapt in response to changes in local environments and global climates. This may include assessing size of populations, distribution of current or potential habitats, potential interchange of genetic material between populations of key species.
Structure		
Stand structure	Management guidelines as affecting key stand features: - canopy density - quantity and quality of snags and coarse woody material - components of herbs and shrubs	

Patch size, shape, habitat "edge"	Size of vegetative blocks to be maintained or created Stand shape index	Horizontal forest structure influence the suitability for meeting the needs of individual animals and maintaining populations. The size , shape and distribution of patches resulting from management activities are compared tonatural patterns as indicators of structural diversity at a landscape scale.
Fragmentation	Amount of "interior habitat" conditions maintained Mi/Km of roads closed seasonally Mi/Km of new roads to be built Road densities	
Habitat linkages	Landscape patterns affecting dispersal and movement Land allocations affecting corridor effectiveness	Patch size is important when evaluating old-growth. Amounts of edge and interior old-growth are indicators of habitat suitability to wildlife associated with old forests. Road density and length of new roads built or closed indicate potential effects on animal species sensitive to hunting, presence of forest opening, or movement. Providing for successful animal species movement helps maintain population persistence. Habitat in critical travel corridors or connectivity can be evaluated in specific watersheds as effectiveness for different species.
<i>Function</i>		
Habitat turnover rates	Percent NF managed at various stand rotation lengths Amount of stand-replacing fires predicted per decade Fire management and prescription strategies Predicted rate of insect and disease outbreaks	
Nutrient cycling and soil productivity	Removal of snags and down logs for fuelwood Replacement and maintenance of snags and logs Area of land burned at low intensity Management of nitrogen fixing plants and fungi	
Fish Habitat Suitability	Tons of sediment produced per area of land Quantity and quality of key habitat features	Indicators of fish habitats...amounts of fine sediments, numbers and distribution of habitat parameters such pools/riffles, large woody debris, presence and density of
Human land-use trends	Hunting and poaching rate predictions Recreation intensity	furtum recruitment to stream channel; water temperature and amount of riparian vegetation; and presence and distribution of invertebrates.
Natural function of ecosystems	Area of land allocated to non-manipulative use Land managed at various timber harvest intensities	Indication of the level of native forest being maintained. The role of fire suppression and exclusion important.

Source: Williams and Marcot 1991

Table 5. Literature Categorization of Species Management Considerations

Source	Species Management Considerations		
	MIS/Ecological Indicators/ Indicator Guilds	Habitat Indices/Matrices/ Risk Asst	Biodiversity (including population processes of viability and persistence)
Adams, J. 1985	X		
Adams, S. 1990	X		
Block et al. 1984, 1987			
Brown 1985		X	
Brussard 1991			X
Cole 1987		X	
Cole and Smith 1983		X	
Cooperrider et al. 1986	X	X	
Davis 1993	X		
DeCamps 1993		X	
Dissmeyer 1994	X		
Erickson and Toweill 1994		X	X
Everett et al. 1994a, 1994b	X	X	X
Fausch et al. 1990	X		
Franklin 1993	X		X
Fry et al. 1984	X	X	
Gaines et al. 1992		X	X
Glenn and Collins 1994			
Graves and Dittberner 1986	X	X	
Hansen et al. 1991, 1993	X		X
Haufler 1994b	X	X	
Haufler and Irwin 1994			X
Henjum et al. 1994	X	X	
Hobbs and Huenneke 1992	X	X	X
Hunsaker and Carpenter 1990	X	X	
Hunter 1990, 1991	X	X	X
Irwin 1994		X	
Irwin and Wigley 1993	X		X
Irwin et al. 1989	X	X	
Jurgensen et al. 1994		X	
Kelly and Harwell 1990	X		X
Keystone Center 1993			X
Kimmins 1990	X		
Kremen 1992	X	X	
Kuusipalo and Kangas 1994			X
Landres 1983	X		
Landres et al. 1988	X	X	
MacDonald et al. 1991	X		
Marcot and Murphy 1992			X
Marcot et al. 1983	X	X	
Martin 1992			X
McCullough and Barrett 1992			X
Mills et al. 1993	X		
Morrison and Marcot 1995	X		
Morrison et al. 1992	X	X	
Nash 1991		X	
Norse et al. 1986			X
Noss 1990a	X		X
Noss and Cooperrider 1994	X		X
Patton 1987	X		

Source	MIS/Ecological Indicators/ Indicator Guilds	Habitat Indices/Matrices/ Risk Asst	Biodiversity (including population processes of viability and persistence)
Patton 1992		X	
Putman 1988	X	X	
Rahel 1990			X
Ruggiero et al. 1994		X	X
Samson 1992			X
Schaeffer et al. 1988	X		
Schroeder 1987	X	X	
Severinghaus 1981	X		
Shaffer 1987, 1991		X	
Short 1982, 1988	X	X	
Short and Williamson 1984	X	X	
Shuter 1990	X		
Szaro and Balda 1982	X		
TFW 1991	X	X	
Thomas 1979	X	X	
Verner 1984	X		
Verner et al. 1984	X	X	
Williams and Marcot 1991	X	X	X
Williams and Neves 1992			X
Woodley et al. 1993	X		

Summary

The selection of indicators to monitor is a critical step in measuring ecosystem health. Forty years of ecological research have identified many such variables and indicators, but there are several problems in selecting an appropriate set of them. At a minimum, the assessment of forest ecosystem health will require measures of vegetation, wildlife, watershed (hydrological) and fisheries/riparian components (O'Laughlin et al. 1993).

As a measure of wildlife condition, relative abundance of a species has been recommended as a high priority indicator by the EPA. However, the concept and use of indicators is not completely accepted by wildlife biologists (Landres et al. 1988, Noss 1990a, Morrison and Marcot 1995). Many of their criticisms include: 1) vague definitions of what the species is supposed to indicate, such as population trends or habitat quality; 2) selection of the species is too general; and 3) the inclusion of threatened and endangered species predicated only on that protected status. Although the different roles of MIS as indicators of habitat abundance, habitat quality, or other wildlife species population trends can be subtle, the distinction must be made for the concept to be useful (Landres et al. 1988).

Physical habitat features may be a more practical indicator (O'Laughlin et al. 1993), but the presence of habitats does not guarantee that animals will occupy it. The implicit assumption in the use of indicators are that they provide a reliable assessment of habitat quality, and that if the habitat is maintained for the indicator species, conditions will be suitable for other species (Landres 1992). Thus, some measure of presence and persistence will also be necessary (Erickson and Toweill 1994). Many have proposed the number, size and arrangement of stands in managed forest landscapes that could be modified to achieve

different wildlife objectives and have hypothesized the response of wildlife species to stand conditions (Thomas 1979, Brown 1985, Irwin et al. 1989). However, less is known about our ability to analyze and predict wildlife responses to varying landscape conditions or the response of wildlife populations and communities at landscape levels (TFW 1991). The difficult task is selecting appropriate species. The interaction and coordination of managers, researchers, and public stakeholders will aid in this task. Irwin (1994) stated that the habitat selection process used by wildlife could perhaps be used in ecosystem assessment if wildlife-habitat models were improved by probing the interactive effects of landforms, soils, and vegetation on the wildlife selection process.

At the least, indicators should be selected and used with care, and examined with the use of rigorously designed evaluation studies. Indicators should not be based solely on best-guess estimates. The prevalent practice is to make "indicators" out of species that already require monitoring (e.g., threatened and endangered species and/or game species), and to rely on existing data bases.

Recommendations to make the use of indicators more rigorous include: a clear statement of goals and objectives of the management initiative; thorough biological knowledge of the indicator(s); and peer review of assessment design, methods of data collection, statistical analysis, interpretations, and recommendations (Landres et al. 1988). The most useful set of indicators will be sensitive to stress (man-induced or natural); be responsive in a predictable way; be easy and economical to measure; and be relevant to the goals of the inventory or monitoring effort (OTA 1992).

MONITORING

The fourth objective of this project was to analyze landscape-level monitoring regimes for fish and wildlife and assess their use as measures of forest ecosystem health. First, we will briefly discuss the concept of monitoring, especially as it relates to forest ecosystem health. Next, we will discuss specific concerns related to the monitoring of fish and wildlife components in the context of understanding forest health. This will be followed by a brief review of the monitoring requirements on federal lands. We conclude with a proposed process for designing a monitoring program.

Monitoring refers to the periodic measurement or observation of a process or object (Clarke 1986). A more detailed definition of monitoring is provided by Goldsmith (1991:2) "monitoring is the intermittent surveillance undertaken to ascertain whether the current conditions (environmental, physical, ecological) match the previously defined standards, expressed as acceptable minimums or maximums or certain defined ranges." In terms of management, monitoring is the process of collecting information to evaluate if the objectives and anticipated results of a management plan are being realized. This type of monitoring that assesses whether activities were carried out as planned is also called *implementation monitoring* (McDonald et al. 1991). McDonald et al. (1991) also defined two other types of monitoring: evaluating whether specified activities had the desired effect (called *effectiveness monitoring*); and evaluating model predictions (called *validation monitoring*).

Why do we monitor? To achieve the broad, societal goal of sustainability, we are interested in preventing any conditions that threaten the benefits of our ecological resources (e.g., diversity, recreation, research, products) and the capacity of the resources to continue to

provide these benefits to society (Hunsaker and Carpenter 1990). Goldsmith (1991) provides three policy-related reasons: to assess the effectiveness of policy or legislation; to comply with regulations; and to detect incipient change ("early warning"). Since the mid-1970s Federal land management agencies have adopted management and planning processes that include monitoring and evaluation of land management plans. Recent work has focused on the need for long-term, integrated monitoring of ecosystems (Everett et al. 1994a, Wissmar et al. 1994) and monitoring at larger scales (e.g., REO 1994, USDA PNW 1994).

Monitoring Fish and Wildlife Resources

To date, monitoring of forest ecosystems and their associated fish and wildlife resources has been piecemeal at best. Overall, monitoring has not been well-designed, effectively implemented, or adequately funded (Everett et al. 1994a, FEMAT 1993, MacDonald et al. 1991, Noss and Cooperrider 1994, Stafford 1993).

A comprehensive monitoring plan that considers the complex array of landscapes, resources, management prescriptions, species requiring attention, and scales is needed (REO 1994). Such a strategy can also provide information which will reduce uncertainty and address the questions surrounding forest ecosystem health, including fish and wildlife components. Of particular importance in designing monitoring programs for fish and wildlife resources, is accommodating the variety of geographic and social scales (e.g., region, province, watershed, communities, administrative units, stands, and site). Monitoring at any scale should: be sensitive to responses of ecological systems from natural events, and from both individual and cumulative management actions; provide acceptable basis for natural resource policy decisions; have standardized data collection; compile, interpret or analyze data systematically; adapt to

various levels of management prescriptions; use indicators or processes that reflect both short-term and long-term responses; and ensure data are analyzed and applied in adaptive management. (McDonald et al. 1991)

Irwin et al. (1989) proposes a wildlife monitoring program at the landscape scale. A broad, responsive monitoring program should be organized around clearly defined, measurable objectives for wildlife diversity. It should be designed to test hypotheses about relationships between wildlife and forest conditions, and how relationships will be affected by alterations in the forest conditions at each level of organization. The monitoring program must incorporate emerging concepts in landscape ecology and landscape experiments designed to improvement management. The variables to measure in an extensive program for monitoring wildlife responses depends upon the objectives for wildlife and habitat diversity. Successful adaptive management requires identification of key wildlife/habitat relationships and a flexible program for monitoring. The focus of these efforts involves evaluating vertebrate responses to various habitat parameters at the stand and at the landscape level. Irwin et al. (1989) utilized an extensive list of habitat parameters and examined the parameters to reflect the following:

- the number of vertebrate classes which have exhibited a relationship with the parameter in question;
- whether the parameter had been identified as important to wildlife;
- the documented strength of the relationship between species response and the parameter;
- the relative use in wildlife-habitat models;
- the type of effort required to gather data; and
- the relative adaptability of the parameter to current timber stand inventory procedures.

Assessing wildlife responses to land use is complicated because environmental gradients constrain the effects of spatial patterning of stands (TFW 1991, Turner 1990). A quantified

understanding of the influences of landforms and soils on animal/plant interactions is required (Haufler and Irwin 1994, Irwin 1994). An ecologically-based landscape classification system can provide a basis for predicting the biological potential of ecosystems, which subsequently will determine the range of management options that affect wildlife (Bourgeron et al. 1994, Covington et al. 1994, Haufler 1994a, 1994b). Generally, monitoring fish and wildlife resources involves collecting fisheries, wildlife and habitat information over time to determine: wildlife use of habitat components; the effects of certain land uses on fish, wildlife and plant species, habitat components and wildlife communities; species or habitat changes caused by natural environmental conditions; the accuracy of predictive models (e.g., Habitat Suitability Index model; Population Viability); and mitigation to protect fisheries or wildlife habitat in an area (from Cooperrider et al. 1986).

Theoretical information and literature available on fish and wildlife as indicators of ecosystem health (species, guilds, habitat features, processes, structures, and functions) were discussed earlier in this report. However, the lack of research and consensus on appropriate indicator selection processes and monitoring methodologies presents a challenging problem for natural resource managers. Table 6 provides a list of monitoring literature addressing general monitoring concepts, monitoring fish and wildlife, and designing monitoring programs.

Federal Monitoring Requirements for Forest Lands

The Forest Ecosystems and Atmospheric Research Act (PL #100-521, 102 Stat. 260) mandates surveys to monitor long-term trends in the health of forest ecosystems. As a result, the National Forest Health Monitoring Program (FHM) was developed. This is a cooperative effort among the USDA Forest Service, EPA's Environmental Monitoring and Assessment

Table 6. Literature on general monitoring concepts, designing monitoring programs and monitoring fish and wildlife.

Source	General Monitoring	Integrated Monitoring/ Monitoring Fish and Wildlife	Design of Monitoring Programs
Alverson et al. 1994	X	X	
BTCA 1994		X	
Clarke 1986	X		X
Cole and Smith 1983		X	
Cooperrider et al. 1986		X	X
Davis 1993			X
Goldsmith 1991	X		X
Graves and Dittberner 1986		X	X
Haug 1983			X
Haynes et al. 1995	X		X
Hicks and Byrdges 1994		X	X
Hinds 1984		X	
Hirst 1983			X
Hoekstra et al. 1983		X	
Hughes et al. 1990	X		
Hunsaker and Carpenter 1990	X	X	
ITFM 1994a, 1994b			X
Irwin et al. 1989		X	X
Joyce et al. 1990		X	
Kremen et al. 1994		X	X
MacDonald et al. 1991		X	X
Marcot et al. 1983		X	
Marcot et al. 1994		X	X
Morrison and Marcot 1995		X	X
Noss and Cooperrider 1994		X	X
REO 1995		X	X
Salwasser et al. 1983		X	
Silsbee and Peterson 1993			X
Smith and Theberge, 1986	X		X
Spellerberg 1991	X		X
Stafford 1993			X
Stout 1993			X
TFW 1991		X	X
USDA - PNW 1994		X	X
Verner 1983		X	
Wissmar 1993			X
Wissmar et al. 1994		X	X
Woodley et al. 1993	X		X

Program (EMAP) and the states (Burkman and Hertel 1992). The structure outlined by EMAP could assist the Forest Service in meeting the requirements of an expanded monitoring program. However, the main focus of the FHM program must be expanded beyond timber resources to monitor fish and wildlife resources and depict regional biodiversity trends.

NFMA monitoring requirements. The National Forest Management Act (NFMA) of 1976 (PL #94-588, 90 Stat. 2949) provides no specific provision for monitoring biological resources. However, the NFMA regulations include monitoring as a component of forest planning. The regulations address monitoring that assesses the impact of timber harvest on soil, water, fish, wildlife, recreation, and aesthetic resources (36 CFR 219.27(c)(6)).

Monitoring to preserve and enhance diversity of plant and animal communities is implied in regulatory requirements for diversity (36 CFR 219.27 (g)). In addition to the diversity provision, the USFS regulations require the forests to maintain viable populations of all "existing native and desired non-native plants, fish, and wildlife species" (36 CFR 219.90), and "planning alternatives shall be stated and evaluated in terms of both amount and quality of habitat and of animal population trends of the MIS [Management Indicator Species]. Population trends of the MIS will be monitored and relationships to habitat changes determined" (36 CFR 219.19 (a)(6)). See Appendix B for current monitoring activities as presented in the Boise National Forest's NFMA-mandated plan (BNF 1991).

There is growing interest in assessing biodiversity within the natural resource agencies (Williams and Marcot 1991). Morrison and Marcot (1995) state that acknowledging the need to inventory and monitor biodiversity would place USDA Forest Service mandated integrated multitresource inventory and monitoring programs in a more realistic framework. Because

forest ecosystems depend on a complex relationship of abiotic and biotic elements, monitoring should integrate biological indicators with societal values to assess effectiveness in conserving biological diversity, long-term site productivity and the sustainability of producing resources for human needs (Everett et al. 1994a). These are what Marcot et al. (1994) identified as the tenets of ecosystem management.

Although federal resource agencies have had experience in attempting to monitor the elements of biodiversity, the means to monitor its component parts and their functions and interactions are not resolved (Morrison and Marcot 1995). There have been long-term discussions within the scientific community and management agencies as to what constitutes appropriate monitoring of conditions and trends. The inadequate treatment of biological diversity has been blamed on the failure to identify measurable attributes of diversity for monitoring programs. Noss (1990a) outlined a characterization of biodiversity that identified three biological components for four levels of diversity (See Table 3, page 40). Williams and Marcot (1991; see Table 4, page 42) applied this outline in designing biodiversity indicators for national forest planning activities.

Monitoring concerns. By concentrating on MIS, many monitoring plans do not meet the standards for monitoring population trends, with some plans proposing to only monitor habitats or infrequently monitor MIS (OTA 1992). Forest inventory and monitoring plans have been criticized for failing to produce an integrated, multiresource program. They have also been criticized for failing to address ecosystem processes and considering appropriate spatial and temporal scales for examining ecosystems. Many plans have been criticized for not being sensitive to statistical requirements for effective data analysis. Many have retrofitted

measures of percentage of total forest acres as a surrogate for animal diversity. Many do not have quantitative measures of the distribution and abundance of plant and animal species and key habitat features.

Problems with monitoring programs are made worse by the lack of: adequate funding (for systematic completion of monitoring plan development or implementation); trained experts (to design and establish programs with adequate monitoring techniques, sampling designs, and statistical analyses); scientific understanding of ecosystem elements, processes, and functions (especially the problem of scale); and validation monitoring for wildlife/fisheries habitat models and the development of advanced models that incorporate landscape classification schemes (e.g., Irwin 1994). Evaluating habitat quality and animal population trends requires models that can evaluate habitat in terms of the capability to support specific species. Many models have been developed and each has inherent strengths and weaknesses.

Federal resource agencies have had years of experience in attempting to monitor elements of biodiversity, the problems are similar and the possible basic solutions may already exist in currently proposed guidelines for monitoring methodologies and strategies to account for changes in biological populations, ecosystems, and communities. See Table 7 for a list of recent works proposing integrated monitoring at landscape scales.

Designing Monitoring Programs and Selecting Parameters to Monitor

A program to monitor fish and wildlife resources and their habitats should follow general underlying concepts, planning and design procedures used for all monitoring programs.

Table 7. Proposed directions on integrated monitoring at landscape scales

Directions for integrated monitoring at landscape scales are included in the following documents:	
◆	EMAP -Environmental Monitoring and Assessment Program
◆	Everett et al. 1994a - Eastside Ecosystem Health Assessment
◆	FEMAT 1993 - Forest Ecosystem Management: An Ecological, Economic and Social Assessment and REO 1994 - Interagency Framework for Monitoring the President's Forest Plan
◆	Haynes et al. 1995 - Scientific Framework for Ecosystem Management in the Interior Columbia River Basin.
◆	ITFM 1994a, 1994b - Water Quality Monitoring for Landscapes
◆	Irwin et al. 1989 - Monitoring Wildlife Response at Different Scales
◆	Noss and Cooperrider 1994 - Monitoring for Biodiversity
◆	PACFISH 1993, BTCA 1994 - Interim Strategies for Managing Anadromous Fish-producing Watersheds in Eastern Oregon and Washington, Idaho; and Bull Trout Conservation Strategy - Idaho.
◆	REO 1995 - A federal Guide for Pilot Watershed Analysis
◆	USDA - PNW 1994 - Section 7 Fish Habitat Monitoring Protocol for the Upper Columbia River Basin
◆	Woodley et al. 1993 - Monitoring for Ecological Integrity

Background Information. The first step in designing a forest health monitoring program which will provide policy makers with information about the effect of forest health problems on fish and wildlife resources is to determine both the present status and historical background for the ecosystem and its fish and wildlife components. Knowledge of the disturbances induced by natural events and human activities is also important. This information can be obtained by defining the landscape in terms of geology, geomorphic landforms, hydrologic regimes, and distribution of fish and wildlife habitats (MacDonald et al. 1991, MacDonald and Smart 1993, Morgan et al. 1994) as well as defining the principal functions and beneficial uses of the ecosystem.

Issues and Challenges. A critical step is identifying the issues and views concerning forest ecosystem health as it relates to fish and wildlife. We must ask and look for answers to questions (Davis 1993) such as:

- What can fish and wildlife tell us about forest ecosystem health?
- What fish and wildlife ecosystem components are important to monitor and why?
- What are the implications to fish and wildlife populations and habitats of changing conditions on the landscape?
- What thresholds are crucial? and
- What is the amount of variation and the scale over which the variation occurs?

Obtaining answers to these questions may require coordination between disciplines; definitions and establishment of relationships of ecosystem components; and recognizing the uncertainty of predictive methods (Wissmar 1993). Finally, obstacles to implementing monitoring programs must be addressed - convincing policy makers, managers and scientists of the importance of long-term ecological monitoring; improving communications and establishing partnerships between agencies and other involved parties to better understand

institutional constraints and to identify mutual concerns and questions; and providing a commitment to the endeavor of designing truly functional monitoring programs.

A Conceptual Model. Design of a long-term monitoring program requires the development of a conceptual model of the ecosystem. Models are composed of system components and their relationships. Perhaps the simplest approach is to consider plant and animal populations, habitats, and constituents of air, water, and soil as the basic components of the ecosystems (Davis 1993).

Schroeder (1987), Thomas (1979), and Verner et al. (1984) provide in-depth discussions of modeling habitat variables in relation to fish and wildlife. Loomis (1993) and Mangun (1991) discuss modeling more in the framework of fish and wildlife decision making. Salwasser et al. (1983) provides a conceptual model for fish and wildlife monitoring using species-habitat production functions or population trends. Verner (1983) provides a conceptual flowchart depicting the interrelationships among elements of an integrated system for monitoring wildlife populations. More recent efforts (REO 1995) have provided models depicting the aquatic and terrestrial elements of ecosystems and their interrelationships. Based on the model, components of the ecosystem which need to be monitored can be identified. However, many ecosystem models are theoretical at this stage and have not been widely applied or tested.

Existing inventories are also important. It is crucial to assess what baseline data is available to produce a picture of the current condition and the quality of the historical data to establish the historical range of variability. It is important to characterize the ecosystem by identifying the standards with which to compare the current conditions. This information has

implications and influences subsequent choices on the issues, management objectives, monitoring objectives, program criteria, and ultimately what indicators to monitor and how to measure them.

Criteria for Program Design. General criteria for monitoring program development and implementation must be identified. These may include considerations such as legal mandates; conflict resolution needs; time; cost and funding commitments; personnel training and skills required; and accessibility and availability of physical and ecological information, including measurement opportunities. Other possible criteria include selecting indicators that: reflect the values of uses of the area; are likely to be affected by management actions; recognize the interrelationships between indicators; and/or are measures used by others so comparison can be made, particularly over time.

Specific criteria have been proposed for selecting fish and wildlife species to be monitored (see, e.g., Davis 1989). It is recommended that species should be chosen that are:

- widespread, dominant, or otherwise important in controlling ecosystem function (selected because of their significance to the overall ecosystem);
- rare, threatened or endangered, or endemic (because of their vulnerability of legal status);
- known to be in flux (to keep track of known cases of change);
- disturbance dependent (because they are likely to be in flux and may require management intervention);
- alien (because they are considered a threat); or
- charismatic (because of public support).

It has also been suggested that more information can be obtained by choosing species to represent a wide variety of ecological roles and life forms than by monitoring a long list of similar species (Davis 1989). Thus, some species might be selected as "indicators" of larger groups or specific processes rather than for their own inherent interest. Although the tradition

of indicator use is well-established in the literature, Landres et al. (1988) pointed out that the identification of criteria in selecting indicators to monitor is crucial. They discussed species-based criteria and community-based criteria and stated that ecological criteria are important whenever a proposed action might affect a population or might alter the structure of a community. The selection of criteria for indicators are often confounded and ambiguous, thus reducing the effectiveness and credibility of using indicators for ecological purposes. In summary, agreement on the criteria used to select the indicators (attributes/parameters) and design the monitoring program is crucial. See Appendix C for literature that discusses criteria for selecting indicators to monitor.

Identify Objectives. The most critical and often most difficult step in developing the monitoring program is defining monitoring objectives. General program objectives should be stated first. Specific legal constraints determine to some extent what attributes a program must monitor or what protocols the monitoring must follow. Other objectives may include the establishment of a baseline for future comparison or for comparison with other areas, or determining the effect of a particular management action. More specific monitoring objectives help determine what to monitor (indicator selection) and how to monitor. Both general program objectives and monitoring objectives must be well defined and prioritized to help resolve any conflicts that arise. Objectives must be clearly defined and prioritized with biological, cultural and political constraints included (Lautenschlager 1996). If this is not done, the result will be broad, ambiguous objectives that provide little direction in developing effective monitoring activities.

Selecting Indicators to Monitor. In monitoring forest ecosystem conditions, we must decide what indicators are appropriate and how we will measure them? The greatest challenge facing scientists and practitioners today is the development of a conceptual framework, selection of representative indicators, and methods to evaluate and monitor the condition and health of the systems we manage (Kessler 1993). Until the appropriate indicators of forest ecosystem health have been selected, measured, and evaluated in a social context, objective judgements about forest health cannot be made (O'Laughlin et al. 1994). At a minimum, the assessment of forest ecosystem health will require measures of vegetation, fish and wildlife, and watershed components (O'Laughlin et al. 1993). [Note: the terms indicator, parameter and attribute are used interchangeably in the monitoring literature and refer to the particular element that is chosen to be monitored.]

While it is difficult to generalize about indicator selection because of the complex nature of ecosystems, the various components of ecological landscape units (i.e., scales such as a national hierarchy of landscape units as proposed in ECOMAP (1993); see also Bourgeron et al. 1994, O'Neill et al. 1986) can be combined into such groups as: vegetation (*key habitats*), soil (landform), water (*hydrology*), biological life (*populations*) [emphasis added], and disturbance patterns, to facilitate efficiency (Hunsaker and Carpenter 1990).

Managers, scientists and decision-makers must reach consensus about the appropriate fish and wildlife indicators to monitor to achieve the stated objectives. Conflict may arise due to interrelated or conflicting or ambiguous objectives. Participants from different disciplines or agencies often have their own set of needs and objectives concerning fish and wildlife aspects of forest ecosystem health.

Monitoring Methods or Procedures. Once the objectives have been agreed upon, decisions must be made with respect to focus. Should the monitoring program focus attention on a few species, communities, or geographic locations, or to try to examine a broad range of resources less intensively? The intensive approach allows more thorough monitoring of the resources considered to be most important or most sensitive, but may not detect important changes in other resources. The extensive approach allows broader coverage of the resources, but only dramatic changes are detectable because sampling intensity is reduced.

Based on the criteria and indicators selected for monitoring, monitoring activities must be chosen or developed. The best approach is to use widely accepted, well-defined methods that already exist (Cooperrider et al. 1986, Davis 1989, Dissmeyer 1994, Hinds 1984, MacDonald et al. 1991) and consult an expert on sampling design, measurement method and statistical design (see, e.g., Gauch 1982, Green 1979).

In summary, the design process consists of the following steps: 1) identifying the issues and challenges of monitoring fish and wildlife in the context of forest ecosystem health; 2) developing a conceptual model of important ecosystem components and process for decision-making; 3) compiling background information concerning existing and historical ecosystem conditions; 4) selecting criteria for program design (general criteria and criteria for parameter selection); 5) identifying monitoring objectives; 6) determining the fish and wildlife indicators for monitoring; and 7) adopting monitoring methods or procedures.

POTENTIAL IMPACTS OF ALTERNATIVE REMEDIAL POLICIES

The final objective of this project was to analyze the potential impacts of alternative remedial policies being proposed for improving forest health and their effects on fish and wildlife habitats. We will begin by reviewing some current proposals and activities on the Boise National Forest. This will be followed by a discussion of current limitations in considering forest health as a management goal.

Boise National Forest (BNF) Strategy

Because of the increased awareness of forest health problems in the Inland West and catastrophic fires in the early 1990s, the Boise National Forest began formulating a forest health strategy which proposed to:

- A. Salvage dead and dying trees in an environmentally sound manner that also recovers economic values;
- B. Thin green stands using silviculture practices and prescribed fire in stands where overcrowding and species mix is contributing to stress and increased risk of total stand loss through dieback or wildfire; and
- C. Study, monitor, learn, adapt, and share information during the process so as to help restore the forest to a condition within its historical range of variability.

The non-governmental organization, American Forests, conducted a policy analysis and evaluation of the BNF strategy in August 1993 (Sampson 1993b). The evaluation concluded that a broader forest ecosystem approach, with *explicit concerns* for threatened and endangered species and other wildlife and aquatic resources, was needed.

Most of the proposed actions in the BNF forest health strategy emphasize intensive management of tree species composition and density to alter conditions and reduce the spread of disease and insect infestation and the risk of wildfire. Many scientists and managers believe this strategy is too narrow and not within the ecosystem management philosophy proposed by federal agencies (see, e.g., Sampson 1993b, Henjum et al. 1994). In response to these concerns, strategies were broadened to include other resources (e.g., water quality, aquatic resources, wildlife, etc). One such response on the BNF was the development of the Deadwood Ecosystem Analysis Project (USDA Forest Service 1994).

Deadwood Ecosystem Analysis Project

The Deadwood Ecosystem Analysis Project (DEAP) began in February 1992, with preliminary public and agency scoping activities and requests for historical information. An interdisciplinary team began completing an analysis of the Deadwood River drainage to integrate scheduled management activities into an ecosystem management framework.

The DEAP looked at the concepts of risk and hazard. The vulnerability or "risk" of forest ecosystems to insect, disease and catastrophic wildfire provides a "hazard" of converting diverse landscapes to homogenous landscapes (USDA Forest Service 1994). The term hazard implies a relative measure of predisposing conditions for damage. High risk timber stands are seen as jeopardizing plant and animal diversity, distribution, dispersal and local population viability (Erickson and Toweill 1994).

The objectives of the project are to:

- "1) restore and maintain the health and long-term sustainability of the ecosystems within the Deadwood River Basin, so that natural processes can be used to maintain the ecosystem in the future;

- 2) maintain species diversity to ensure healthy and viable populations of all the native species of flora and fauna characteristic of the Deadwood River Basin;
- 3) minimize risks to users and maintain long-term ecological integrity along the southern portion of the Deadwood River corridor;
- 4) compare existing ecological conditions with historical conditions and determine a historical range of variability for use in developing standards or desired future ranges of conditions);
- 5) ensure long-term persistence of the aquatic ecosystem;
- 6) prioritize treatment of sites with high risk from catastrophic fire;
- 7) treat other sites in order to avoid or reduce the severity of fire;
- 8) map recreational sites and determine sites that compromise the integrity of the area; and
- 9) monitor to evaluate effectiveness in meeting the goals and objectives of adaptive management techniques to achieve desired conditions. " (USDA 1994: 4-1).

The Forest Supervisor signed the proposed action report (PAR) on September 1, 1994.

This report was a landscape level prescription and stated the desirability of achieving forest health and ecosystem management for the Deadwood River drainage (USDA 1994). The PAR stated that "monitoring of changes across the landscape will be crucial to the success of this project as to allow for adaptive management as monitoring results indicate needed adjustments" (USDA 1994: 4-1). Based on the ecosystem analysis, a five year plan of project proposals was to be developed to meet the objectives for the area.

Deadwood Fish and Wildlife Analysis. The DEAP used succession and vegetative structural stages to address wildlife habitat potential. Suitable habitat for certain species is influenced by cover types, structure class of each habitat type, and the disturbance factor. The amount, location and distribution of suitable habitat for each species are dependent on patch size, dispersal and distribution of critical vegetation cover type and forest structure class. "Specialist" wildlife species require individual or specific habitat needs and must be addressed at the site level (Table 8). "Generalist" species have broad or general habitat requirements and

Table 8. Unique habitat requirements for threatened and endangered species and management indicator species considered to be "specialist" wildlife species from the Deadwood Ecosystem Analysis Project (USDA 1994).

Species by SC and CT	1	2	3	4	5	6	R	B	W	L	limiting habitat required at the Site level
Bald eagle - nesting						X					2 miles around reservoir, large ponderosa pine on ridges
Fisher					X	X					Denning: CCC-C (>70%) near water Forage/corridors: CCC-B&C (>40%)
Northern goshawk					X	X					Nesting habitat: 30 acres, CCC-C, high density of large dbh trees, <60% slope, N aspect.
Boreal owl					X	X					Engelmann spruce, subalpine fir HT, high elevation, 1 sq. mile, <80° temperatures
Flammulated owl					X	X					DRY HT, Fire Groups 2&3, in SC# 5&6, CCC-A&B (30-60%)
White-headed woodpecker					X	X					Ponderosa pine/Douglas-fir (dry HT sites), CCC-A&B (20-60%)
Three-toed woodpecker					X	X				O	Engelmann spruce, subalpine fir, lodgepole pine HT, bogs, CCC-C (closed)
Great gray owl	X	X			X	X			X		Foraging: meadows & openings next to nesting habitat Nesting: lodgepole pine, CCC-C (closed), 0-10% slope
Spotted frog									X	X	0-1% slope stream, silt/sand/muck substrate, ponds
Mule deer	X	X						X			Winter range forage on E/S/W aspects & low elevation
Red-backed vole					X	X					CCC-C (closed) & down woody debris
Pileated woodpecker					O	X					16-17 live 20" dbh TPA, CCC-B&C (30-100%) @ 300 acres, SC# 6 next to SC# 5

SC: Structure Class (1: grass forb shrub, 2: Seedlings saplings, 3: Poles saplings, 4: Immature trees, 5: Mature trees, 6: Over Mature trees) CT: (R: rock outcroppings, B: Brushfields, W: riparian & meadows, L: Bodies of water). CCC is Canopy Closure Class where Class A is 0-39% closure, Class B is 40-59% and Class C is more than 60% closure. HT is Habitat Type and TPA is Trees Per Acre.

a large home range that can be identified at the landtype association level using structure class and cover type information (Table 9).

The DEAP proposed to use a landscape level computer model (Forest Vegetation Simulator) along with habitat requirements for threatened, endangered, sensitive, management indicator, or species of concern to provide information to determine habitat availability. This would be analyzed using a hazard-risk model (BNF 1995) to relate existing habitat and potential risk. Finally, a comparison of existing and predicted conditions from alternatives would determine habitat persistence.

At about the same time as the PAR was signed, and following discussions with various forest personnel, it was decided that the DEAP would be a good case study to use in our project. Fish and wildlife could be assessed as part of the forest health debate and the monitoring design guidelines proposed earlier in this report could be tested. The focus would be on developing a forest health monitoring program that included fish and wildlife indicators that were linked to the landscape-level ecosystem focus of the project.

The first step of the case study was to bring local fish and wildlife experts together to discuss the biological priorities of the Deadwood area. This was completed in late June, 1995. The two-day discussion focused on a review of: criteria for indicator selection; fish and wildlife indicators for monitoring the Deadwood ecosystem; and monitoring objectives based on the goals of the Deadwood Project. A separate report is being developed that contains the outcomes of this workshop. The intended next step was to identify a panel of secondary reviewers consisting of selected regional scientists to examine the monitoring design

developed. The final step was to be a review by the forest and district level decision-makers of the monitoring priorities and recommendations.

The BNF was proceeding under this 1994 strategy for the Deadwood ecosystem and we were in the midst of our project at the time that the Taylor-Gorton Amendments to the 1995 Rescission Bill HR 1158 (Emergency Two-Year Salvage Timber Sale Program) became law in July, 1995 (PL 104-19). This rider, commonly referred to as the Salvage Rider, mandates the use of salvage, thinning, prescribed fire management, and other logging activities at landscape scales to treat the forest health emergencies as defined by Congress.

Deadwood Salvage Sale Area

In response to the passage of Salvage Rider, the original Deadwood Ecosystem Analysis Project has changed. It has been broken down into smaller site specific projects and the analysis is now the Deadwood Salvage Sale. An environmental assessment should be completed soon. The need for the salvage sale is based on information from the earlier landscape analysis which suggested that the area is likely to experience uncharacteristically large scale, high intensity fires or insect or disease out-breaks, due to the dense forest stands and species composition. There is a desire to reduce the likelihood of these events. The proposed actions (USDA 1996a) include the following strategies to address forest health:

- prescribed fire;
- sanitation salvage then prescribed fire;
- sanitation salvage with precommercial thinning;
- precommercial and commercial thinning favoring lodgepole pine;
- two to five acre clearcuts; and
- prescribed fire in subalpine fir habitats.

The proposed actions have been designed to reduce the number of trees per acre, alter the tree species mix (e.g., increasing ponderosa pine and Douglas fir), increase the variety of size and age classes, salvage insect killed and damaged timber, and reduce ground fuels and ladder fuels. Deadwood salvage sales are expected to take place over the next several months.

Many interested parties were encouraged when the Deadwood Ecosystem Analysis Project was formulated as a multi-functional document that attempted to look at all components of the ecosystem and incorporate other objectives into the purpose of the project, including fish and wildlife values and concerns. This was a positive opportunity to open dialogue between those with differing perspectives and it provided an avenue to address the concerns of these stakeholders. However, with the passage of the Taylor-Gorton Amendments, the focus and opportunity to expand forest health into the realm of ecosystem health has been narrowed to a focus on the harvest and use of timber, reducing the importance of fish and wildlife priorities in forest health restoration initiatives.

Cache Salvage Sale Area

As a consequence of the change in the purpose and timeframe of the Deadwood Project, the Cache Salvage Sale (USDA 1996b) will be used as an example of a sale that has been prepared after the Salvage Rider went into effect. An environmental assessment (EA) was prepared under the provisions of the Salvage Rider. The purpose of this project is to provide the initial step in the rehabilitation and recovery of insect infested and diseased timber stands by removing infected trees and those at risk to attack by insects. Included in the environmental assessment is a brief assessment of the impacts of the salvage sale actions on fish and wildlife.

Tables 10 and 11 are provided as representative examples of probable impacts to wildlife within an area proposed for salvage logging.

Table 10. A comparison between Alternative 1 (do salvage logging) and Alternative 2 (no action) for the Cache Salvage Sale of key habitat components and threatened and endangered species and management indicator species that use the habitat (Source: USDA 1996b).

Key Habitat Components	Species	Alt. 1	Alt. 2
Ungulate prey base	Gray wolf	High	High
Wolf Vulnerability	Gray Wolf	Reduced due to road closures	No change in current levels
Human disturbance short term	Wolf, Ungulates, Wolverine	Increase due to project activities	No change in current levels
Human disturbance long term	Wolf, Ungulates, Wolverine	Lowered due to road closures	No change in current levels
Mature /early-seral edge effect	Lynx/hare, Ungulates, Wolverine, great gray owl	Increase	No short term change
Mature/Old-Growth forest	Red-Backed Vole, Pileated Woodpecker	Reduced	Reduced in the long term
Continuous forest canopy	Flamulated Owl,	Decrease	Decrease in long term
Large & Small Snags	Owls, Woodpecker, Mtn. Chickadee	Slight decrease	Short term increase
Trees with nest or cavities	Owl	Retained	No change
Downed woody debris	Red-backed Voles	No change	No change
Riparian, Wet areas, Meadows	Spotted Frog, Meadow Vole, Yellow Warbler	No change	No change

Table 11. A summary of the effects on sensitive species under Alternative 1 (do salvage logging) and Alternative 2 (no action) for the Cache Salvage Sale based on the Biological Evaluation (Source: USDA 1996b).

Cache Salvage Timber Sale			Alternatives		
Species	Habitat	Occurrence	1	2	-
Spotted Bat (<i>Euderma maculatum</i>)	Rock crevices high up on steep cliff faces.	No habitat in area. No species expected.	NI	NI	-
Western Big-eared Bat (<i>Plecotus townsendii</i>)	Caves & abandoned mine tunnels.	No habitat in area. No species expected.	NI	NI	-
North American Lynx (<i>Felis lynx canadensis</i>)	Boreal & high-elevation forests, snowshoe hare habitat.	Habitat in area. Species not found.	MIH	MIH	-
Wolverine (<i>Gulo gulo</i>)	High elevation forests, talus slope den sites, limited human disturbance.	Habitat in area. Species expected.	MIH	MIH	-
Fisher (<i>Martes pennanti</i>)	Mature/old-growth spruce-fir forest near water. Down woody debris hiding cover.	Habitat in area. Species not found.	MIH	MIH	-
Northern Goshawk (<i>Accipiter gentilis</i>)	Nest in 30 acre mature/old-growth forest, closed canopy, slopes <30%.	Habitat in area. Nests not found.	MIH	MIH	-
Boreal Owl (<i>Aegolius funereus</i>)	High elevation mature spruce-fir forests, Obligate cavity nester.	Habitat in area. Species not found.	NI	NI	-
Mountain Quail (<i>Oreortyx pictus</i>)	Tall, dense brush around or near a water source, riparian below 5000' elevation.	Habitat in area. Species not found.	NI	NI	-
Flammulated Owl (<i>Otus flammeolus</i>)	Mature ponderosa pine & Douglas-fir forests, open canopy. Obligate cavity nester.	Habitat in area. Species expected.	MIH	MIH	-
White-headed Woodpecker (<i>Picoides albolarvatus</i>)	Mature pine/fir trees, dry/warm sites, open canopy. Large snags.	Habitat in area. Species expected.	NI	NI	-
Three-toed Woodpecker (<i>Picoides tridactylus</i>)	Wet sites or subalpine fir habitat types, foraging & nesting snags.	Habitat in area. Species expected.	MIH	MIH	-
Great Gray Owl (<i>Strix nebulosa</i>)	Lodgepole pine/subalpine fir next to small openings or meadows. Use platform nest.	Habitat not in area. No species expected.	NIH	MIH	-
Spotted Frog (<i>Rana pretiosa</i>)	Silt/sand/muck substrate of permanently wet riparian areas.	Habitat in area. Species expected.	MIH	MIH	-

NI: No impact; MIH: May impact individuals or habitat, but will not likely contribute to a trend towards a federal listing or loss of viability to the population or species.

Fish species identified in the area of the Cache Sale include two anadromous species and six inland species (e.g., bull trout, cutthroat trout). Both short-term and long-term effects have been selected as important considerations for fisheries, with impacts to bull trout serving as the indicator of impacts to other resident fish. The EA acknowledges that timber harvest and road construction have the potential to adversely affect fishery habitat by delivering sediment to spawning and rearing habitat (USDA 1996b:47). No new roads will be constructed; however, existing roads will be reconstructed and have the potential to deliver sediment to the stream area. These sediment changes are identified as being the only impact to fish and fish habitat, both in the short and long-term (USDA 1996b:48). The EA further states that the effects of the proposed alternative on fish habitat would potentially be an initial short-term slight degradation of fish habitat quality, followed by a long-term slight improvement in fish habitat quality in area streams. Both the short- and long-term effects would be negligible and not measurable (USDA 1996b:51).

For wildlife, species considered in the EA include threatened and endangered species, sensitive species and the Management Indicator Species as identified in the Forest Plan. Elk Habitat Effectiveness (EHE) is proposed as the indicator for wildlife. The EA identifies several potential impacts to wildlife based on the proposed alternative. These include: an increase in the current level of human-caused disturbance; displacement of wildlife in the harvest area; removal of dead and dying trees that provide hiding cover, nest cavities and large woody debris within the system; and an increase in forest edge due to clearcutting activities. However, the EA states that, although activities would last for several years in the entire

project area, the proposed actions are not expected to cause permanent adverse effects for several reasons:

- 1) most activities are localized, would be of short duration, and would only cause displacement to individuals from the immediate area;
- 2) there are adjacent undisturbed areas where animals can move to avoid human contact;
- 3) disturbance levels are expected to decrease slightly after activities are completed;
- 4) timing of activities would restrict adverse disturbances to non-critical periods to protect nesting birds and wintering ungulates. However, some prescribed burning and pre-sale activities would occur during critical periods causing displacement of individuals; and
- 5) additional cumulative disturbances associated with other projects having similar effects are expected to occur at different times, and there would be undisturbed areas between projects where animals could escape (USDA 1996b:56).

Little monitoring is discussed in the EA. Thus, the actual ecosystem impacts, either positive or negative, from this sale may remain unknown.

Concerns

Many scientists have voiced their concerns about the potential impacts to fish and wildlife when salvage logging activities are used to "treat" forest health. These scientists are not completely opposed to salvage operations, especially in areas where: access already exists, opportunities to regenerate forests are good, fish and wildlife values (including cover) may be

enhanced, and watershed damage is likely to be minimal. However, they are concerned that salvage operations are moving forward without long-term plans for the restoration of forest health and the plans do not adequately assess fish and wildlife opportunities and constraints. Many also contend that salvage sales are proceeding outside the framework of ecosystem management and little monitoring and evaluation to guide subsequent direction and gain knowledge is being done.

DellaSala et al. (1995) has voiced some of the strongest concerns relating to current forest health strategies. They state that many misconceptions concerning forest health strategies exist, including beliefs that: 1) intensive management techniques, when applied at landscape scales, are effective at reducing the frequency and intensity of catastrophic fire; 2) clearcutting and other logging activities mimic natural disturbances; 3) insects and disease would quickly destroy forests if not controlled by intensive management; and 4) late-seral forests should be logged in some watersheds to return them to within their estimated historical ranges of variability.

Testimony from the Wildlife Society at hearings on salvage logging indicated that although salvage and thinning may benefit some dense tree stands, these techniques may increase risk to forest resources other than timber, such as wildlife species that thrive in habitats with high basal areas or those that rely on high levels of forest structure or canopy. These scientists are concerned that salvage and thinning to alleviate threats from insects, disease, and fire are moving forward without adequate analysis of the impacts on other resources such as fish, wildlife, water quality and soils. The Society also pointed out that no consensus exists on silvicultural practices for minimizing the effects of drought, fire, insects, and

pathogens; or the conditions that warrant managing Late successional/Old Growth (LS/OG) to reduce the risk of catastrophic loss; or on the levels of treatment that reduce risk without compromising ecological values. In addition, information concerning current levels of LS/OG may be inadequate to protect fish and wildlife resources.

Henjum et al. (1994) found that salvage logging that removes a substantial proportion of standing, downed, or potential future coarse woody debris is detrimental to most LS/OG forest organisms. Dead trees (particularly large dead trees) generally have multiple ecological roles in the recovering landscape, including habitat for a variety of species, and functioning as an important structural element in biological and physical processes. Research is needed on the role of dead wood in terrestrial ecosystems -- in particular, how much wood should be left on a site and across the landscape to provide for the full range of ecosystem processes and the needs of species (Beschta et al. 1995).

Many scientists have also voiced concerns regarding logging activities and road construction and their potential impacts to stream areas, especially accelerating the delivery of sediment to streams in areas of steep slopes, shallow soils, unstable geologies, and intense storms. Roads also increase access and, subsequently, increase the vulnerability of certain wildlife species. A final concern expressed is that research to support intensive salvage logging and other activities that are hypothesized as being able to reduce the risk of fires or mimic natural disturbances at large temporal and spatial scales is critically needed.

CONCLUSIONS

It is obvious from this review of the voluminous literature that has been produced in the past decade, that there has been much discussion about the issue of forest health. Historically, the emphasis centered on the risk of mortality to trees from insects, disease and catastrophic fire. In the past five years, the issue of forest health has rapidly expanded to the concept of forest *ecosystem* health with an emphasis on analyzing, managing and sustaining ecosystems. This report reviewed the evolution of our land management philosophies and the role that fish and wildlife resources play in the forest health debate. However, the limitations of forest health as a management goal are both numerous and readily apparent.

Forest health is a concept; it may not be realistic as a forest management goal. Should the goal of a healthy forest be based solely on ecological criteria or should it include socio-cultural perspectives? Based on our current level of knowledge about ecosystems and landscape-level analysis, we cannot determine health from an ecological standpoint. And, as a society, we have not determined what we consider a healthy forest. At this point, forest health best represents a conceptual way to look at opportunities and constraints as we move forward in the evolution of our land management philosophies.

The often-stated forest management objective "to restore or maintain the health of the ecosystem" is not directly measurable with the current state of knowledge we have of forest ecosystems. We may be able to indirectly index "health" by assessing the number of disease or insect-infested trees, the animal species present, or the presence or absence of unique habitats. Also, the broad concept of forest health may be acceptable, albeit subjective, but we do not know how to do complete inventories to assess the current situation based on the

concept of "forest health" as discussed in the literature. Neither can we agree on the establishment of a threshold that indicates *healthy* and monitor to see if it is being approached or exceeded.

To achieve forest health, a set of landscape conditions must be identified and decided upon in light of biological, political and cultural *realities*. Therefore, *priorities* for fish and wildlife resources, as part of forest ecosystems, need to be identified from a biological standpoint and within the context of political realities and cultural values. Today, there is a significant amount of ambiguity about societal and management goals for fish and wildlife habitats and populations across landscapes and what distribution of habitats or abundance constitutes a healthy ecosystem.

Although the use of indicators to assess the status of management has had much opposition in the past, it is still an established method to analyze the impacts of disturbance on fish and wildlife populations and habitats. Management agencies choose indicators as surrogate measures of the health of an ecosystem. At our current state of knowledge and understanding, there is not one indicator or set of indicators that can be formulated to assess whether a landscape or ecosystem is healthy. Fish and wildlife biologists need to reach agreement regarding the *criteria* to use to select indicators and the *indicators* themselves.

There is extensive research on predicting impacts to some species and some habitats, particularly at site-specific scales and in the short term. However, we are severely limited in determining fish and wildlife species responses to disturbances at larger spatial and temporal scales. The level of our knowledge concerning such concepts as connectivity, persistence, viability, and diversity over landscape scales is still in its infancy. Data are not conclusive in

regards to specific habitat requirements for species. Models have not been validated with long-term monitoring data. We have a long way to go to be able to understand and predict the consequences to fish and wildlife of what is being proposed to remedy the forest health situation. Priorities for fish and wildlife must be included in the planning and implementation of "forest health" activities.

Some argue that priorities for fish and wildlife are included in the larger efforts to address forest health. For example, an objective to maintain the diversity of all native flora and fauna within a ecosystem and ensure healthy and viable populations may be seen as addressing priorities for fish and wildlife. However, this objective is not biologically measurable nor politically realistic. What is still lacking is agreement on the specific species, habitats, and ecosystem features that are of concern in relation to the management activity. Objectives which can be measured and monitored are needed.

In addition, the critical issues for fish and wildlife will most likely be specific to an area or ecosystem. Substituting an analysis of impacts on species and habitats from one plan to the next is not adequate. Priorities for an area must be established and agreed upon by the public and the political decision-makers. Not everything can be measured or monitored in light of available funding, time, and human resources. Adaptive management, said to be a key to an ecosystem management approach to natural resource management, needs to be incorporated into current forest health initiatives.

Once impacts to species are predicted, monitoring must be carried out to determine or validate these predictions. Natural resource agencies have been criticized in the past for a lack of commitment to monitoring long-term effects or validating model predictions.

Monitoring at larger scales or for long-periods, has said to be too expensive and time-consuming. Monitoring was identified as a needed activity twenty years ago with the passage of the NFMA and its implementing regulations. Today we are still discussing the problems inherent in and the lack of coherent sound monitoring activities. Well-developed monitoring plans with measurable objectives are needed. They must accurately reflect what is possible and what is most important to accomplish under staff and budget constraints and public interest.

Real limitations exist in the status of our ability to understand ecosystem elements and landscape processes and functions. Real limitations also exist concerning funding availability. However, we should not allow these limitations to be impediments to moving forward in our understanding of forest health and how to achieve it. Other "limitations" require risk-taking on the part of agencies to effectively implement changes in management philosophies which may not be in accordance with long-ago stated missions or current political views. We need to establish management priorities and monitoring objectives based on biological, political and cultural criteria, to begin to bridge the gap amongst the variety of stakeholders who express interest in the health of our forests.

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APPENDIX A

Wildlife/ Fisheries Concerns in the Forest Plan for the Boise National Forest

Wildlife/ Fisheries Concerns BNF Forest Plan

Current Forest Management

Traditionally, wildlife habitat management in the Forest has focused on mitigation of logging and livestock activities with additional incidental habitat improvements. Current philosophy is shifting from this "protectionist" approach to one of aggressive habitat management. This change is based on the recognition that long-term maintenance of wildlife habitat is strongly tied to successional diversity and to the avoidance of catastrophic fire and insect/disease losses. It recognizes the critical role of timber, and of fuels management as tools to accomplish long-term wildlife objectives.

Implementation of this philosophy requires identification of specific wildlife objectives and development of silvicultural prescriptions to meet them. It relies on a flexible commercial and fuelwood timber program, extensive fuels management, and intensive road management.

Management indicator (MIS) species are animal species that help indicate the effects and influences of land management on wildlife and fish. Habitats used by management indicator species will be monitored to determine what population changes, if any, are induced by management activities. Indicator species and reasons for selection are:

Wildlife Management Indicator Species

Indicator Species	Reasons for Selection
Elk	Important big-game species; significantly affected by timber management. Indicator of successional summer ranges and good high-elevation meadow management. Monitoring data available.
Mule Deer	Most popular big-game species on the Forest; significantly affected by grazing and timber management. Indicator of successional summer and winter ranges. Monitoring data available.
Red-backed Vole	Species closely tied to old-growth habitats with high crown cover and ground litter in shaded, damp understory conditions. Easy to monitor.

Meadow Vole	Species closely tied to moist meadow and streamside habitats with good cover and litter. Riparian indicator species. Sensitive to over-grazing. Easy to monitor.
Pileated Woodpecker	Requires snags greater than 20" dbh in mature and old-growth habitat. Has local and scientific value. Represents wide range of large snag users.

Mountain Chickadee	Requires snags of at least 4" dbh. Primary and secondary cavity user. Eats insects gleaned from tree foliage. Readily monitored. Year-round resident.
Yellow Warbler	Indicator of several types of riparian habitat (including deciduous vegetation and shrubby, wet meadows). Identified as "sensitive species" by USFWS. Readily monitored.

Fisheries Management Indicator Species

Indicator Species	Reasons for Selection
Native Trout (cutthroat, rainbow/redband, bull trout)	Juveniles have specific environmental requirements and are relatively intolerant of polluting substances and environmental changes. Popular sport fish of significant economic value. Listed as a "species of special concern" by Idaho Department of Fish and Game
Anadromous Fish: Chinook Salmon	Juveniles have specific environmental requirements and are relatively intolerant of polluting substances and environmental changes. Popular sport fish of significant economic value. National and State concerns over protection and enhancement of chinook salmon populations.
Anadromous Fish: Steelhead Trout	Juveniles have specific environmental requirements and are relatively intolerant of polluting substances and environmental changes. Concern over the protection and enhancement of steelhead runs. Listed as a "species of special concern" by the Idaho department of Fish and Game.

APPENDIX B

Current Monitoring Information in Forest Plan

Current Monitoring Information in Forest Plan

The following describes the element to be monitored, the procedures for monitoring, and the frequency and intent of the monitoring activity. The table is structured to include three levels of monitoring defined as:

- Implementation Monitoring - Used to determine if plans, prescriptions, projects, and activities were implemented as designed, and in compliance with the Plan.
- Effectiveness Monitoring - Used to determine if plans, prescriptions, projects, and activities are effective in meeting management direction, objectives, and standards.
- Validation Monitoring - Used to determine if initial data, assumptions and coefficients in the development of the Plan are correct.

IMPLEMENTATION MONITORING

MONITORING ELEMENT	ACTION, EFFECT OR RESOURCE TO BE MONITORED	MONITORING PROCEDURE	FREQUENCY	DATA RELIABILITY	INTENT OF MONITORING	EVALUATION RESPONSIBILITY
Water	Application of Best Management Practices (BMPs), and soil and water conservation practices	Field review (in conjunction with post-project audits; see ML, Planning)	Annually 10% of timber projects	High	Determine if BMPs implementation is in compliance with Idaho water quality laws	Watershed Staff
Riparian (all resources) Water and Soil, Fisheries, Wildlife, and Range	Riparian Area Management	Field review (May be in conjunction with post-project audits See ML, Planning)	Annually (Selected projects)	Moderate to High	Determine if riparian standards are implemented and check progress of moving toward Riparian Value Class goals	Range, Watershed & Wildlife Staffs
Planning	All resources - project and improvement activities (fish and wildlife, watershed)	Post-project audits (review by Management and/or ID Team)	Annually 1 project per District minimum	High	Determine whether projects are implemented as planned	Planning and Resource Staffs

EFFECTIVENESS MONITORING

MONITORING ELEMENT	ACTION, EFFECT OR RESOURCE TO BE MONITORED	MONITORING PROCEDURE	FREQUENCY	DATA RELIABILITY	INTENT OF MONITORING	EVALUATION RESPONSIBILITY
Fisheries	Management Indicator species	Snorkel counts or fish shocking	Every 2 years (20 stations)	Moderate/ High	Determine trend of management indicator species	Fisheries Staff
Wildlife	Elk Habitat	Compare predicted Elk Habitat Effectiveness (EHE) values with Forest Plan Elk EHE objectives	5 year summary	Moderate	Determine long-term elk habitat trend	Wildlife Staff
Wildlife	Deer habitat Elk Habitat	Monitoring winter range condition and rehabilitation progress and success	5 year summary	High to Moderate	Determine long-term deer and elk winter range habitat trend	Wildlife Staff
Wildlife	Pileated Woodpecker and red-backed vole	Review old-growth acreage (timber strata inventory)	Once every five years	Moderate	Determine long-term habitat trend	Wildlife Staff
Wildlife	Meadow vole (riparian species)	Monitor riparian vegetation used by voles	3 years	Moderate	Determine long-term trend and riparian habitat condition	Wildlife Staff
Wildlife	Eagle	Monitor active nests	Annually	High	Determine long-term habitat/population trend	Wildlife Staff
Wildlife	Snags	Monitor snag densities on the Forest through the Stand Exam Process	Annually	High	Determine long-term habitat trend for cavity-nesting birds	Wildlife Staff
Water Resources and Fisheries Monitoring	Fish habitat and stream channel monitoring	Substrate, channels and water quality (e.g., % fines, cobble embeddedness, sediment, photo or physical measurements)	Annually at 30 stations	Moderate/ High	Determine long-term trend for comparison to Land Management Planning Goals, objectives and standards	Fisheries and watershed staffs

Water Soils Fisheries	Change in water quality due to land management activities; monitor representative BMPs in range, timber recreation and minerals	Standard methods of water quality, erosion, sediment, and fish habitat measurements	Annually (selected projects)	Moderate to High	Validate that BMPs are effective in protecting beneficial uses as required by Idaho water quality standards	Watershed and Fisheries Staff
Riparian Water and soil Fisheries Wildlife Range	Riparian area management	Vegetation and green line transects, soil productivity, fish habitat, and stream channel parameters	Annually (concentrate on Riparian Management Priority areas)	Moderate	Determine attainment of riparian standards and goals; develop data for extrapolation to similar sites on Forest	Range, Watershed, and wildlife Staffs

VALIDATION MONITORING

MONITORING ELEMENT	ACTION, EFFECT OR RESOURCE TO BE MONITORED	MONITORING PROCEDURE	FREQUENCY	DATA RELIABILITY	INTENT OF MONITORING	EVALUATION RESPONSIBILITY
Wildlife	Elk	Review aerial count data by IDFG	Every 5 years	Moderate	Determine population trend	Wildlife Staff
Wildlife	Deer	Review aerial count data by IDFG	Annually	Moderate	Determine population trend	Wildlife Staff
Wildlife	Bald eagle	Bald eagle count	Annually	High	Determine population trend	Wildlife Staff
Wildlife	Wolf	Inventory of wolf sightings	Annually	High	Determine population trend	Wildlife Staff
Wildlife	Meadow vole (riparian species)	Pre- and post-activity snaptrap surveys	Every 3 years	Moderate	Determine population trend	Wildlife Staff
Water	Sediment yield/fishery response models	Compare model results with actual sediment yield and fish habitat conditions (selected watersheds)	Annually	Moderate	Improve and/or refine predictive models (BOISED and FISHED)	Watershed and Fisheries Staff

Source: BNF 1991

APPENDIX C

Literature Source - Presentation of Suggested Criteria for Selecting Indicators to Monitor

Literature Source - Presentation of Suggested Criteria for Selecting Indicators to Monitor

Davis 1989	• Widespread, dominant, or otherwise important in controlling ecosystem function selected due to their significance to the overall ecosystem) • Rare, threatened or endangered, or endemic (because of their vulnerability of legal status) • Known to be in flux (to keep track of known causes of change) • Disturbance dependent (because they are likely to be in flux and may require management intervention) • Alien (because they are considered a threat) • Charismatic (because of public support)
MacDonald et al. 1991	Selected Parameter(s) = function (objectives of monitoring, designated uses of resources, management activities, costs and environmental setting) • Qualitative assessment of the effects of water quality monitoring parameters on major designated uses of water • Sensitivity assessment of water quality monitoring parameters to management activities • Frequency and costs data or sample collection by monitoring parameters • Interrelationships among water quality parameters
Noss 1990a	• Sufficiently sensitive to provide an early warning of change • Distributed over a broad geographical are or otherwise widely applicable • Capable of providing a continuous assessment over a wide range of stress • Relatively independent of sample size • Easy and cost-effective to measure, collect, etc • Able to differentiate between natural cycles or trends and those induced by anthropogenic stress • Relevant to ecologically significant phenomena
Kelly and Harwell 1990	Purposes of indicators: • Intrinsic importance Key : indicator is the endpoint Economic species Endangered species • Early warning indicator Key: rapid indication of effect • Sensitive indicator Key: reliability in predicting • Process indicator Key: endpoint is process Monitoring other than biota Complement structural indicators • Indicator of ecosystem sensitivity/vulnerability Key: system attribute Abiotic indicators • Ease/economy of monitoring • Feedback to regulation or management Adaptive management potential Hierarchial suites of indicators
Noss and Cooperrider 1994	• A good measure of or surrogate for the element you are concerned with • Early warning capabilities • Experimental controls or benchmark (of the indicator) are available • The way in which a change in an indicator beyond a threshold will stimulate a change in management • The relationship between the indicator and the element of interest is well-documented and defensible

Woodley et al. 1993	• Ecologically meaningful - closely related to maintenance of essential environmental processes and ecosystem functions • Macro scale - indicate changes in entire communities rather than selected species • Sensitive - quickly respond to stresses and perturbations • Simple - are easy to measure
Day 1990	1) Definition of the problem as an objective to point to indicator. 2) Is being applied nationally or over broad geographic regions important? A type of measurement can be compared across regions, i.e., a chosen indicator should represent the same niche in the ecosystem but obviously the actual species may differ. A problem occurs with a species that can migrate/emigrate/immigrate because they may be stressed in one region but be sampled in another. Do we need to choose species with a restricted range in the ecozone? 3) Is the indicator locally related to stress caused by humans? This criterion actually relates to the question of geographic distribution, it means that the indicator must be stressed where it is sampled. 4) Scientifically defensible? Needed to ensure acceptance by scientific community and appropriate application of the indicator. This relates to the assumptions inherent in the use of indicators and the inference to other species and communities. 5) Adequate historical record and projected availability of ongoing/future data sets - baseline data? Needed to 1) identify long-term trends; and 2) determine whether an indicator serves as an integrator of accumulated stress inputs or reflects short-term response to pulses in the environment. 6) Reliability and consistency of types of measurement used to assess indicators? To ensure that comparisons of temporal and spatial trends are credible. Quality control (QA/QC) and sampling design considerations. 7) Simplicity [Feasibility]? A) less controversy among scientific community B) minimize cost/effort of monitoring programs 8) Data generally should be quantitative? Needed to evaluate long-term trends - but qualitative representations should not be discarded.

Landres et al.
1988

- Sensitivity -

Effective indicators are sensitive to the environmental conditions or habitat attributes of concern. Two assumptions are explicit in this criterion. 1) sensitivity should be related to habitat attributes by cause and effect, not merely correlation - then the influence if habitat change on population attributes of the indicator may not be separable from influences of other regulating factors (e.g., weather, disease, etc.). 2) management agencies are necessarily restricted to selecting indicators that are sensitive to habitat attributes that the agency can control (**). In contrast to this criterion - an increase in abundance of insensitive or tolerant species may provide information on habitat conditions (***). However, caution is necessary because the density of such species may increase for reasons unrelated to the environmental conditions being managed.

- Variability of Response -

An effective indicator must exhibit low levels of variability in response to the environmental factors of interest. Alternatively, the contribution from each significant source of variation must be identified.

- Specialist versus Generalist -

It has been suggested that specialists are better indicators because they are more sensitive to habitat change. Use of specialist is advocated on the assumption that meeting their needs will provide for generalists as well (USDI 1980b). However, caution rests with the fact that some species need a combination of habitat types in certain proportions and spatial arrays and specialists may be less abundant than generalists - leading to problematic sampling and higher costs. It is recommended that if indicators are used, they exhibit a demonstrated relationship to habitat attributes of interest, and not be selected solely on the basis of whether they are generalists or specialists.

- Residency Status -

Indicators of on-site environmental conditions should be permanent residents. However, assessment objectives may specifically include monitoring of migrants that breed on managed lands, or of environmental conditions in areas used by migrants during winter.

- Area Requirement -

If a single species is used as an indicator of habitat quality or of a community, it is commonly assumed that the species should require a large area for its territory or home range. The indicators would have a greater area requirements than any other species in the community, thus the larger the area required the more likely it is to include the spectrum of resources needed by other organisms dependent on that habitat. However, such a species (e.g., umbrella species Wilcox 1984) may more easily adjust to changes in the environment by shifting its use of resources within its home range, integrating adverse and beneficial effects.

- Size -

Suggested that species of large size are better indicators than smaller species, because larger species exhibit slower turnover rates and therefore are more stable. Turnover rate can be interpreted as population turnover (generation time) or species turnover (change in species composition at a given location). Caution is suggested and it is recommended the scale of disturbance relative to the indicator and species of interest be determined. To track short- and long-term responses to environmental perturbation, it may be important to monitor both small and large species to document population effects over both short and long temporal scales.

Noss 1990a	Five categories of indicators that warrant special conservation effort - including monitoring: • ecological indicators - species that signal the effects of perturbations on a number of other species with similar habitat requirements • keystone species - pivotal species upon which the diversity of a large part of the community depends • umbrella species - species with large area requirements which if given sufficient protected habitat area will bring many other species under protection • flagship - popular, charismatic species that serve as symbols and rallying points for major initiatives • vulnerable species - species that are rare, genetically impoverished, dependent on patchy or unpredictable resources or otherwise prone to extinction.
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